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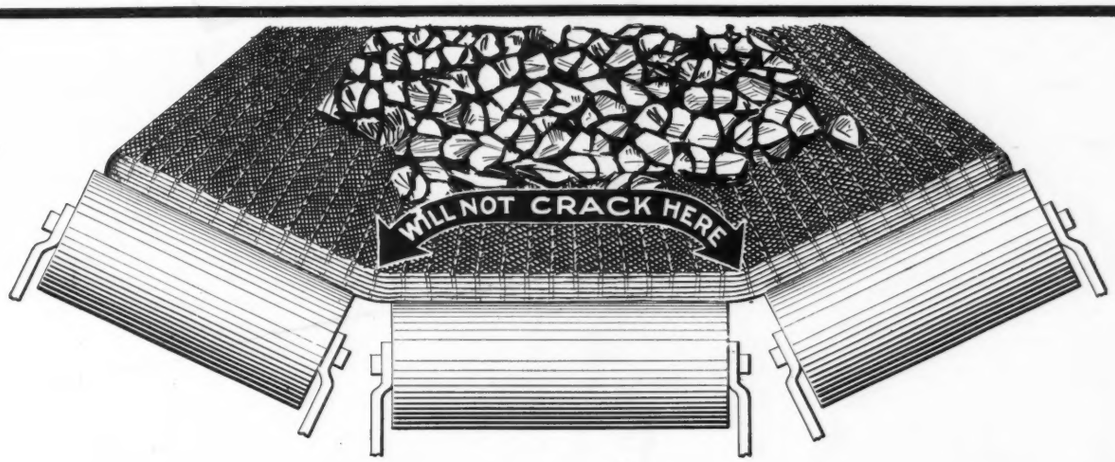

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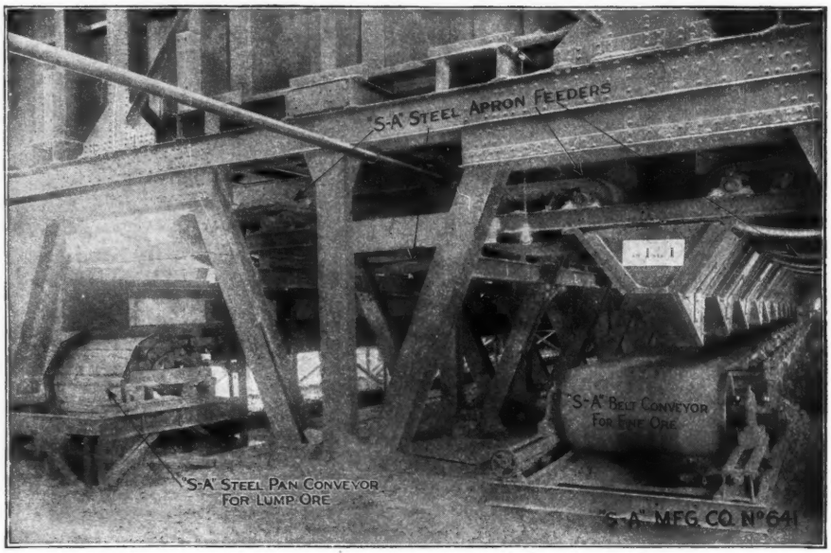

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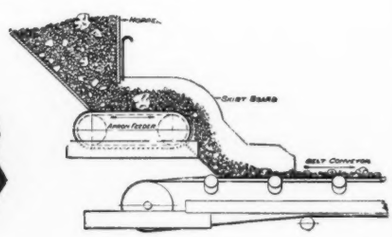

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Engineering and Mining Journal

VOLUME 101 FEBRUARY 12, 1916 NUMBER 7

The Second Pan-American Scientific Congress

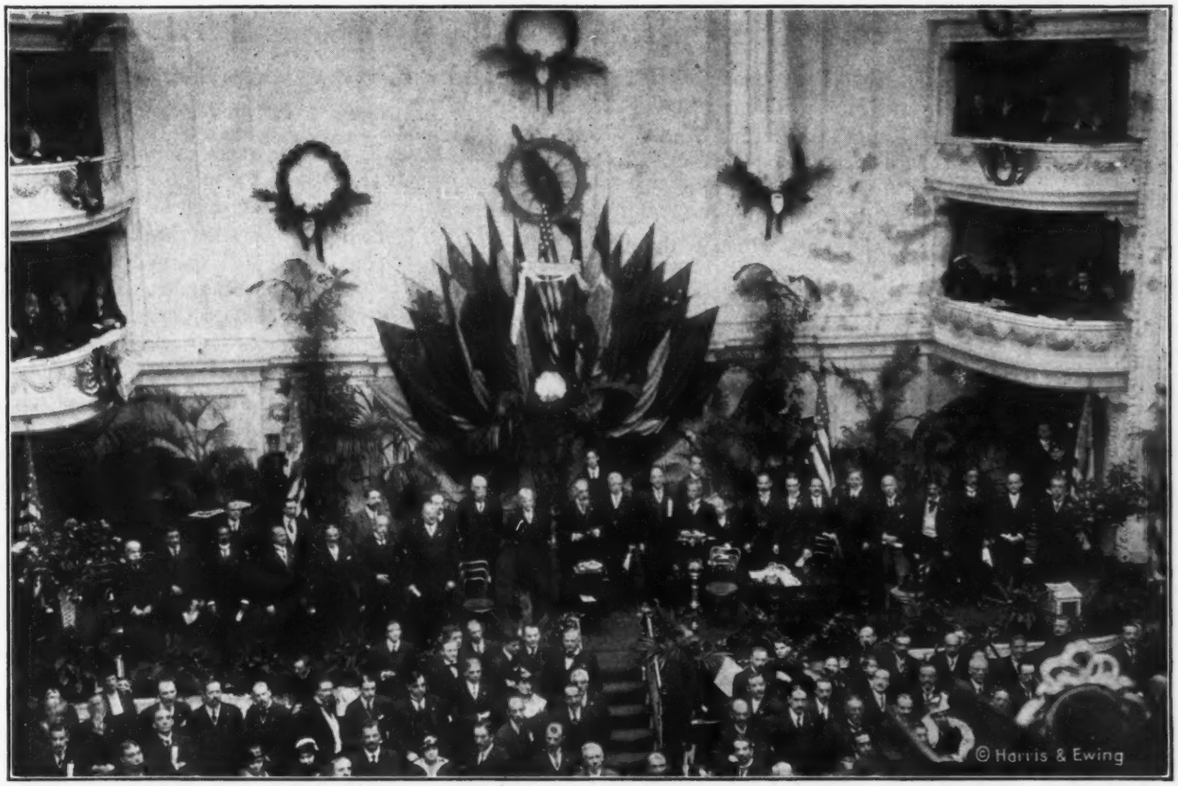
SYNOPSIS—More than 1,000 delegates at opening of session, Dec. 27, by Hon. John Barrett. The Chilean ambassador acted as chairman of convention. Section VII devoted to mining and metallurgy at which meetings many important papers were presented. Various committees composed of some of the most prominent members of the profession.

More than one thousand delegates from the 21 American republics and a large gathering of diplomats and interested spectators witnessed the calling to order of the second Pan-American Scientific Congress[1] by Hon. John Barrett, the secretary-general, in the Continental Memorial Hall, Washington, D. C., Dec. 27. On the stage were the diplomatic representatives of the various Latin-American republics to Washington, and in the boxes overlooking the stage were many distinguished ladies. The background was a beautiful collection of the flags of all the Americas, with guards in the uniforms of the United States Army, Navy and Marine Corps, in attendance.

Secretary-General Barrett introduced the president of the congress, His Excellency Eduardo Suárez Mujica, the ambassador of Chile and chairman of the delegation of that country. The ambassador then presented in turn the Vice-President of the United States, Hon. Thomas R. Marshall, and the Secretary of State, Hon. Robert Lansing.

Plans for the unity of all American countries and discussion of ways and means to bring about even closer harmony in the future marked all of the meetings. The congress, which concluded on Jan. 8, was a noteworthy gathering and will go down in history because of the part with which it will be credited in the development of "International Americanism," in addition to its contributions to the world of science in all its branches.

[1]As outlined in "Eng. and Min. Journ.," Jan. 1 and Jan. 15, 1916. The first was held at Santiago, Chile, Dec. 25, 1908, to Jan. 5, 1909.



THE OPENING OF THE SECOND PAN-AMERICAN SCIENTIFIC CONGRESS

There was a large attendance of South Americans, but unfortunately only a few belonging to Section VII—the mining and metallurgical section. There was, however, a large attendance from the United States.

All sessions were open to the public, but the receptions were restricted to members. Since the close of the congress the visiting delegates are making an extensive tour of the United States, visiting various points of interest and the larger cities, where officials and organizations have appointed committees and arranged to entertain them.

Probably no larger or more comprehensive effort to get the people of various countries together has ever been carried out. During the congress there were in simultaneous session under the various sections and subsections upward of 30 meetings daily, dealing with a wide range of subjects.

The executive committee of the congress was composed of the following distinguished men:

William Phillips, Third Assistant Secretary of State, chairman ex officio.

James Brown Scott, secretary, Carnegie Endowment for International Peace, vice-chairman.

William H. Welch, president National Academy of Sciences, honorary vice-chairman.

John Barrett, director general Pan-American Union.

W. H. Bixby, brigadier general United States Army, retired.

Philander P. Claxton, Commissioner of Education.

William C. Gorgas, surgeon general United States Army.

William H. Holmes, head curator Smithsonian Institution.

Hennen Jennings, former president London Institution Mining and Metallurgy.

George M. Rommel, chief Animal-Husbandry Division, Bureau of Animal Industry, Department of Agriculture.

L. S. Rowe, president American Academy of Political and Social Science.

Robert S. Woodward, president Carnegie Institution of Washington.

The work of the congress was taken up by sections, of which there were nine, under the following heads: Sec. I, Anthropology; Sec. II, Astronomy, Meteorology, and Seismology; Sec. III, Conservation of Resources; Sec. IV, Education; Sec. V, Engineering; Sec. VI, International Law, Public Law, and Jurisprudence; Sec. VII, Mining, Metallurgy, Geology and Chemistry; Sec. VIII, Public Health and Medical Science; Sec. IX, Commerce, Finance and Taxation.

Section VII, of which Hennen Jennings was chairman, was divided into four subsections, which with their respective committees were:

SUBSECTION 1—MINING

Van H. Manning, director of the United States Bureau of Mines, Washington, D. C., chairman.

J. F. Callbreath, secretary of the American Mining Congress, Washington, D. C.

C. H. Lindley, lawyer, authority on mining law, San Francisco, Calif.

E. W. Parker, director of the Anthracite Bureau of Information, Wilkes-Barre, Penn.

H. C. Perkins, mining engineer, Washington, D. C.

G. S. Rice, chief mining engineer of the United States Bureau of Mines, Pittsburgh, Penn.

W. L. Saunders, engineer, president of the American Institute of Mining Engineers, New York, N. Y.

B. B. Thayer, past-president of the American Institute of Mining Engineers, New York, N. Y.

SUBSECTION 2—METALLURGY

W. R. Ingalls, president of the Mining and Metallurgical Society of America, and editor of the "Engineering and Mining Journal," New York, N. Y., chairman.

F. G. Cottrell, chief chemist of the United States Bureau of Mines, San Francisco, Calif.

R. H. Richards, professor emeritus of mining engineering and metallurgy, Massachusetts Institute of Technology, Boston, Mass.; former president of the American Institute of Mining Engineers.

Bradley Stoughton, metallurgical engineer, secretary of the American Institute of Mining Engineers, New York, N. Y.

L. D. Ricketts, mining and metallurgical engineer, New York, N. Y.

Karl Eilers, metallurgical engineer, New York, N. Y.

W. R. Walker, metallurgist, New York, N. Y.

G. H. Clevenger, professor of metallurgy, Stanford University, Calif.

SUBSECTION 3—ECONOMIC GEOLOGY

George Otis Smith, Director of the United States Geological Survey, Washington, D. C., chairman.

J. C. Branner, president of Leland Stanford Jr. University, Stanford University, Calif.; former president of the Geological Society of America.

J. F. Kemp, professor of geology, Columbia University, New York, N. Y.; former president of the American Institute of Mining Engineers.

Waldemar Lindgren, professor of economic geology, Massachusetts Institute of Technology, Boston, Mass.

C. R. Van Hise, president of the University of Wisconsin, Madison, Wis.; former president of the Geological Society of America.

David White, chief geologist of the United States Geological Survey, Washington, D. C.

I. C. White, state geologist of West Virginia, Morgantown, W. Va.; formerly chief of the Brazilian Coal Commission.

Bailey Willis, consulting geologist to Argentine Government; geologist, United States Geological Survey, Washington, D. C.

SUBSECTION 4—APPLIED CHEMISTRY

Charles E. Monroe, authority on explosives; dean of graduate studies, George Washington University, Washington, D. C.; former president of the American Chemical Society, chairman.

Carl L. Alsberg, chief of the Bureau of Chemistry, Department of Agriculture, Washington, D. C.

C. H. Herty, president of the American Chemical Society, Chapel Hill, N. C.

B. C. Hesse, chemist, New York, N. Y.

W. F. Hillebrand, chief chemist of the United States Bureau of Standards, Washington, D. C.; former president of the American Chemical Society.

F. A. Lidbury, electrochemist; president of the American Electrochemical Society, Niagara Falls, N. Y.

P. C. McIlhiney, chemist; chairman of the New York Section, Society of Chemical Industry, New York, N. Y.

Harvey W. Wiley, chemist; former president of the American Chemical Society, Washington, D. C.

Next Congress To Meet at Lima, Peru, in 1921

At a meeting of the executive committee Lima, Peru, was unanimously selected as the meeting place of the third Pan-American Scientific Congress, to take place in the year 1921. The centenary of Peruvian independence will be in the same year.

The motion to select Lima was made by His Excellency Eduardo Suárez-Mujica, ambassador of Chile and president of the congress. It was seconded by Dr. Julio Philippi, vice-chairman of the Chilean delegation.

The minister from Cuba, Dr. Carlos Manuel de Cespedes, who is also chairman of the Cuban delegation, stated that the Cuban delegation intended to invite the congress to Havana, but on account of 1921 being Peru's centenary Cuba was pleased to withdraw.

The committee then voted unanimously for Lima and applauded its selection as evidence of the harmony and good will characterizing the congress.

The United States Government appropriated in all $85,000 for this congress, and with that money the organization was perfected and carried out.

In addition there were 53 members of the congress who came as guests of the Carnegie Endowment, but who were also invited by the Department of State on the same basis as the unofficial delegates. The expenses of these guests were borne by the endowment.

Improved Mining and Metallurgy an Aid to Conservation*

By Dr. L. D. Ricketts†

SYNOPSIS—Cheaper mining methods, lower extraction costs and greater recovery permit the exploitation of large bodies of low-grade ore; the introduction of new processes of beneficiation, larger smelting furnaces, and electro-static methods of dust precipitation, play a most important part in effecting conservation.

True conservation means really improvement of processes and avoidance of waste. The present generation is entitled to take and will take from the earth that which it justly needs, provided it does not wreck and destroy and unduly waste a part of the earth's resources and provided that any partially beneficiated substances are stored and held for future treatment. This deduction comes from the fact that as we have accumulated and continue to advance in knowledge future generations can utilize material that is at the present time uncommercial or dispense with the use of the product in whole or part. When the question of the conservation of our mineral resources came up during Roosevelt's administration, there were estimates made showing the limited amount of iron, copper and other ores available for use in the arts, but as I recollect it, these estimates simply referred to material that was then available and commercial and did not refer to the immense masses of leaner material that were not then commercial.

Attention should be brought furthermore to the important advance in the metallurgical processes, and especially in the mining and metallurgy of copper ores which have resulted from the organized efforts of large and efficient technical staffs working in harmony and in unison. The wonderful results obtained have been the work of no one man, and the advance has been the result of wise and intelligent coöperation.

Effect of Cheaper Mining Methods

Wonderful progress has been made by this means in decreasing unit costs and in improvements in process and recoveries. In mining we originated in America and followed, for a generation or more, the square-setting and filling system, which is still important in rich ore masses. Later this was followed by the so-called caving systems, which abandoned an attempt to hold up ground that cannot be held up, with usually a mattress of timber between the overburden and the ore. Such caving systems involve either slicing or subslicing to provide for reinforcements and maintenance of an efficient mattress. The caving systems have been borrowed from the iron industry by the copper mines. These methods have been followed by so-called shrinkage methods that have still further decreased the cost of mining, although they require the holding of great masses of broken ore underground for long periods of time. Another method is being put into practice, requiring far less storage of broken ore underground and also avoiding the mattress—a system somewhat similar to the shrinkage system, excepting that far less ore stands broken and a single horizontal pillar is maintained under the caving ore instead of a horizontal pillar and numerous vertical pillars, and excepting that a far smaller quantity of ore is broken by mining methods and a far greater quantity by the natural crushing of the mass. I refer to the so-called Ohio system of mining, as improved and developed by Mr. McDonald at Inspiration. Through these efforts the unit cost of mining has been tremendously decreased and we have been enabled to mine exceedingly low-grade material and convert it from uncommercial rock into commercial ore.

Lower Extraction Costs and Greater Recovery

In connection with beneficiation it has been necessary to cheapen greatly the unit costs and at the same time to increase largely the metallurgical recovery. The fact that the leaner copper ores mostly occur in enormous tonnages warrants large capital expenditure and the construction of the most economical and highest class of power plants, dressing works and reduction works.

Flotation has proved to have a tremendously important bearing on the increased recovery of copper from sulphide ores, and it would appear that within reasonable limits the percentage of recovery from the sulphide remains constant, even if, through a cheap mining method, the ore is necessarily mixed with a proportion of overburden that is valueless. In other words, it seems practicable with cheap power and very fine grinding and the use of flotation to dress cheaply lean copper ore and make a recovery of 90% or over of the copper existing as sulphide in the ore whether the ore contain 2% or 1% of copper. In using the term flotation I mean, of course, that simple and modified methods of gravity concentration are used in conjunction with it, if the sulphide mineral be very finely disseminated and the ratio of concentration is high; while the gravity methods somewhat simplified remain the major process, and flotation simply supplements it where there is some coarse sulphide and the ratio of concentration is low.

With reference to the reduction of the copper concentrates and copper ores there has been notable improvement in the increased size of the furnaces; the use of fuel oil or powdered coal in reverberatory furnaces; the introduction of static-electric methods for avoiding dust losses; the introduction of basic lining in copper converting; and improvements in refining. I should say, however, that the advance made in smelting and refining processes in no way compares in importance to the advance made in mining lean ores and dressing them preparatory to smelting.

Another subject that we are all interested in is the treatment of lean oxidized copper ores by leaching, and electrical precipitation of the copper with a partial regeneration of the acid consumed, and while commercial plants of large size are only beginning to be installed, the outlook for the profitable recovery of copper from lean carbonate and silicate ores hitherto valueless is exceedingly promising.

*Paper presented at the Second Pan-American Scientific Congress, Washington, D. C., and published by permission.

†Mining and metallurgical engineer, 42 Broadway, New York.

At the present time, under most advantageous conditions, I have no hesitation in saying that 1¼%, and possibly 1%, sulphide copper ore having a high ratio of concentration can be developed and mined by underground methods and beneficiated at a profit, and that the same statement will probably apply in the near future to oxidized copper ore in the form of carbonate and silicates; and just as such ore was uncommercial and worthless 10 years ago, so I believe similar ores containing but 0.6 or 0.7% copper will become commercial in the next decade.

My theme, therefore, is that in the conservation of our resources we must remember that organized investigation and study of mining and metallurgical processes play a tremendously important part, for if we can bring to the point of commercial use leaner and leaner ores, so can we greatly extend, almost indefinitely extend, the life of our mineral industries.

We should also remember that so-called waste products such as slags, tailings, etc., containing small quantities of metals, but now unprofitable, may in turn become exceedingly profitable. They should therefore be stored and held for future use.

From the viewpoint of conservation we must recognize that an organized struggle to increase our profitable reserves through decreased unit costs and improvements in process and consequent higher recoveries presupposes the accurate collection and tabulation into useful form of an immense amount of detail in both investigation and operation.

The great improvements made and those still to be attained can only come with accurate knowledge, not only of costs, but of grades and recoveries. To attain better results we must have complete knowledge of what we are doing at the present time. In almost all metallurgical statements there is an item called "unaccountable loss." As a matter of fact we should not recognize any such thing as an "unaccountable loss." We should only recognize that owing to imperfect methods there is a loss for which we have not accounted.

It is true that in well-developed mining organizations the principles I have outlined are recognized, but I think in the Pan-American congress, where countries are involved whose mining industry is in its infancy, attention should be brought to these principles of conservation, for we all know that in the early history of mining in this country the loss to the world through the waste of ore underground and of half-treated products has been enormous.

Buying and Selling Nonferrous Metals of South America*

By Ludwig Vogelstein†

SYNOPSIS—Transatlantic trade and shipping controlled by Great Britain gave her the control of the Chilean copper output when Chile's production was 23% of the world production and exceeded that of the United States. Inadequate smelting and refining facilities of the United States in the second half of the Nineteenth Century also helped force control of copper markets on England. Ore buying formerly done by banking concerns instead of mining men or smelters, and advances are universally necessary. Greatest diplomacy required of ore buyer in South American field; he must be a good mixer, good story-teller, have a copper-lined stomach, an iron constitution and be a gentleman.

The mineral wealth of the South American Continent was the prize that led Pizarro and Cortez to their discoveries in the early part of the Sixteenth Century. We are told that when Pizarro conquered Peru, or what was then Peru and is now partly Chile, he found immense stores of gold, silver and other metals, and that Cortez in his conquest of Mexico seized large quantities of precious as well as of base metals. We further know that the Spanish Empire was glutted with the gold and silver that came from the newly discovered territories during the latter part of the Sixteenth and the early part of the Seventeenth Century. As a matter of fact, the flow of precious metals from South America has never entirely ceased, although a great many mines that were operated at the time of the discovery of the continent long since ceased to operate and have been abandoned.

So far the exploitation has been principally confined to the west coast of South America, although some mining of the less valuable metals as well as of the precious metals has been done on the east coast. The nonferrous minerals produced on the east coast are relatively not of great importance except from Venezuela and the Central American state of Honduras.

A new impetus was given nonferrous metal production in South America about the middle of the Nineteenth Century, after Chile had gained her independence. Up to that time only high-grade ores, principally oxides and carbonates, had been smelted in charcoal furnaces, but in 1842 Charles Lambert built at Coquimbo the first reverberatory furnace in Chile and in 1857 the first blast furnace. The Chilean copper production became soon an important, and to some extent the governing, factor in the world's market. Even in 1890 the production of Chile was still about 10% of the world's production. In 1911 it had fallen to 3.4%, but since then some increase is noted.

Great Britain's Control of Chilean Metal

At the time when South America began to be an important factor, the copper industry and copper smelting were practically, if not entirely, controlled by Great Britain, and it was natural under those circumstances that most of, if not all, the Chilean product should gravitate to Great Britain. In consequence of this situation and of the fact that the transatlantic trade and shipping were in the hands of Great Britain, South America became accustomed to the methods, terms, prices, etc., of British smelt-

*Paper presented at Second Pan-American Scientific Congress, Washington, D. C., and published by permission.

†Of L. Vogelstein & Co., 42 Broadway, New York.

ers and refiners. This was the more natural in view of the fact that sterling drafts were at all times considered the unchanging and unchangeable money standard of the world, and particularly so in South America, where monetary conditions were unstable.

Smelting and mining enterprises developed quickly in Chile. In 1882 their production of copper reached 43,000 tons, the total world's production at that time being 181,000 tons and that of the United States 40,467 tons. In other words, in 1882 the production of Chile was about 23% of the world's production, while the United States' output was 22%.

In view of the great distance from the market and of the financial necessities of a young mining country, Chile bars were consigned through South American banking firms to their British connections and sold in the London market. After 1865 this was done through the London Metal Exchange, which then became a factor in the world's market. A firm of brokers in Valparaiso was finally recognized as the impartial intermediary between seller and buyer and obtained such a hold on the market that practically no copper was sold or could be sold except under its auspices.

In those early days of the second half of the Nineteenth Century the smelting facilities of the United States were so inadequate that we had to dispose of a part of our own product in Great Britain. Even a large portion of the first production of the Anaconda mine was smelted in Swansea. Only with the beginning of the '80s did a change in this respect begin slowly to work its way, but it gained headway year by year, so that at the present time—and for the last 15 years—the United States is recognized as the most efficient smelter and refiner of base and precious metals in the world. This result was achieved partly in harmony with the general industrial development of this country and partly owing to the tremendous strides toward the exploitation of our immense natural resources, which is evidenced by an increase of the copper production of the United States from 27,000 tons in 1880 to 546,000 tons in 1913; or expressed in percentage, in 1880 the United States produced 17% of the world's production of copper against 55% in 1913. In a similar way the silver production of the United States has changed from 30,318,700 oz. in 1880 to 66,801,500 oz. in 1913, while in gold the United States has held a prominent position which was only relatively reduced by the development of gold mining in South Africa.

Rise of United States Copper Refining

The pioneer in copper, lead, silver and gold smelting in the Eastern States was the Balbach Smelting Works, whose plant was brought into prominence in the '80s through the adoption of the electrolytic copper-refining process. Soon after, the Baltimore Copper Co. built at Baltimore a large and modern plant, which was used to a great extent for the treatment of ores from the Anaconda mine after that company had emancipated itself from Great Britain. The Nichols Copper Co. and the Perth Amboy plant of M. Guggenheim Sons were also started during this period.

For a long time several factors stood in the way of attracting South American ore to the United States. In the first place, both for copper and silver London's importance as a market could not be disregarded. The operations of the Secretan Syndicate made the London market very attractive to Chile, as up to 1888 Chile bars were the only product deliverable on the London Metal Exchange. During the Secretan corner Chile bars brought even higher prices than refined copper. Another factor that stood in the way of attracting business to the United States was the lack of shipping and banking facilities. A third factor, which is not unimportant and particularly not unimportant in a Spanish-American country, was the conservatism of shippers. Personal friendship between buyer and seller and the habit of having their settlements made in a certain way to which they had become accustomed tended to hold the trade in its old channels.

Up to the beginning of this century ore buying in South America had not been handled by men particularly familiar with the mining and smelting business, but rather had been done principally by banking concerns. With the development of the smelting industry all over the world and, above all, in the United States, the need of qualified ore buyers made itself felt, and several firms established agencies in the South American field. Incidental to this work, or rather, coincident with it, the mineral wealth of South America and particularly of the countries on the Pacific Coast attracted the attention of capitalists. This is not the place to review the important development that has occurred during the last 20 years, but there is no doubt that the establishment of large mining enterprises in South America under the auspices of citizens of the United States has helped to bring about a change in ore- and metal-buying methods of the Southern Continent. At the beginning the American ore buyers, as well as the American miners, were regarded with suspicion and were classed with adventurers who had preceded them, many of whom had left unsavory reputations. Only when it was seen that by perseverance and a steady flow of money results could be achieved was a greater confidence in the methods of the North American States established.

Difficulties Met by American Ore Buyer

The American ore buyer had to combat many difficulties. The British method of accounting for metals and ores is cumbersome enough, but the Chilean method was even more complicated, owing to the variation in exchange and the practice of the banking fraternity in South America to assume this risk of exchange by guaranteeing a fixed rate on a given date. The most astonishing practice had crept into the business, of paying for metals and ores as much as 30 or 60 days before they were shipped. In the meantime the buyer, who at the same time was the banker, had in his hands nothing but a paper obligating the shipper to deliver within a certain period to the buyer or in case of nondelivery to pay interest.

The usual contract stipulates that during a certain period the owner will deliver the mineral output of his property and the buyer will receive and pay for such deliveries at contract terms. Nothing sounds fairer, but the way it usually works out is that deliveries are heavy while quotations are high, which is the very time when buyers wish to avoid the market risk. When quotations are low, deliveries diminish and frequently cease. The buyer is told that the miner cannot make money at prevailing prices; or the company is without funds, or supplies have not arrived; or a break has occurred in the

transmission line; or the pumps are out of order; or that a holiday season is on; or what not. About this time the ore buyer is apt to receive a cable reading: "We are short of ore. What will you ship?"

The ore buyer must then become a diplomat, for the cry of distress from the northern smelter whom he represents must not go unheeded. He cannot go to the miner and offer better prices, for the chances are that he is already paying all that ore is worth. He cannot argue that metal prices are apt to go lower, because an error in forecasting the market will be remembered and he will be mentally debited by the miner for whatever loss the latter believes he has sustained. What he does is to mingle with his clients and tell them that his principals are anxious for ores; he makes an appeal to their sense of fair play by showing how with deliveries all at high quotations there will be difficulties in renewing contracts, and explains that while low quotations prevail labor is cheap and prospecting for future days should be undertaken.

This campaign will result in promises and some ore. The promises he must translate into tonnage as best he can; the ore must be seen and its value estimated, so that he can know with some degree of certainty the quantity that will reach port in time for steamer's departure. He must frequently travel to the mines to see whether he is getting the output. A miner that needs money may forget that he has a contract and deliver to the local merchant or banker, who will advance more money against the shipment than the ore buyer believes safe. The ore buyer relies upon his friends to keep him informed of the development of prospects, progress at mines, movement over roads, activity of competitors and export shipments, and is not afraid to be seen consulting with his competitors over points of mutual interest, for in South America there is no Sherman Law.

Need of Money by South American Operators

Money is more urgently needed in the mining field of South America than in North America, for many native companies, after receiving money for their products and as soon as they have paid pressing debts, proceed to divide the surplus in the form of a dividend, so as to advance the price of their shares. In all parts of the world mining is apt to be looked upon as a gamble, but in South America it is more hazardous than in northern lands, for the regions are not thoroughly prospected. A reserve or sinking fund is rare, and the ore buyer is expected to advance money to work the mine. Often he is asked for a loan upon the property to enable the miner to go to work.

When a front of ore is uncovered, the ore buyer is invited to inspect it at his own expense in hopes that he may loan more money, so that operations may be extended. After the ore is extracted, he is urged to anticipate payment; when it arrives at the station, he is besieged for funds to be repaid from the next shipment; and when the shipment finally reaches port, he must advance for it, according to the contract. Hard is the fate of the ore buyer in South America who becomes enthusiastic and for a single moment forgets that he is a business man and advances money upon a mine. He must then study most carefully the laws of the land and must be a foster parent to the property, for all its ills will affect him, and the utmost he can expect is the return of the money he has advanced. His principals will blame him for making loans, but in ore buying the one at the front must break rules if he can see that the result will be favorable.

I have devoted considerable time to advances because that one tendency causes more trouble than all other acts in ore buying. The ore buyer wants ore and often goes far afield to secure it. He is a philanthropist, for he is building up the country through his investments. He should not advance money until ore is sampled, weighed and assayed and in his possession, but they all do it in spite of warnings and resolves.

It is to be hoped that the investor in mining shares or properties will come to realize that an adequate working capital is often the salvation of a property. The ore buyer, like the banks, forces the borrower to pay for loans or accommodations. Large mines should finance their own operations. Small mines must be borrowers, but they should borrow from the local bank and be independent of the ore buyer.

Even today a considerable quantity of ore from South America finds its way to market through local merchants, banks or shipping companies, though an ore buyer may be resident in the neighborhood. These intermediaries send the shipment to market, and their correspondents turn it over to an ore buyer, who accounts for it at market rates. The miner receives less for his product than had he sold direct to the ore buyer, but has enlisted the interest of a local capitalist. He always has in mind the necessity of credit or money for operating expenses. The capitalist is well paid. He receives generous interest on the money advanced and a substantial commission for his services and also for the services of his correspondent. South American merchants are always in need of exchange to cover their purchases abroad, and for this purpose ores are as convenient as money, besides saving a banking commission, or they may even be enabled to sell exchange and thereby collect a commission or profit thereon. Truly they catch the miner "coming and going."

Ore Buying a Game or a Business

North American ore buyers are apt to become unpopular in South America, for they often fail to realize that the making of a deal is a game that the South American enjoys. It is too often a game of wits rather than cold business. The North American prefers to state his terms, explain them if requested and have them accepted or rejected. But if he pursues this plan, it shows lack of experience and will result in failure. He must first of all cultivate friendly relations with his client, show interest in his property by examining the mine and learning its history, look at all the specimens that the miner has gathered, then gradually discuss conditions. The Peruvian wants to sell his copper based on the price of Best Selected; the Chilean wants the Standard Three Months' quotation; the Venezuelan and Colombian are used to the quotation for Electrolytic Wirebars. If the ore buyer has an alert mind and a sharp pencil, he need not combat his clients' desires as to a basis for settlement. South Americans have been used to shipping to British and German smelters so long that they prefer the settlements made in those countries, and the ore buyer who ships to New York will have to demonstrate that a fair deal will be given. On account of the South American's desire to settle for his shipments prior to exportation, the up-

todate ore buyer must be prepared to receive, weigh, sample, assay and pay for shipments before forwarding them to his smelters in the North. In this way he prevents shipments going to Great Britain and Germany, as would possibly otherwise occur. The miner of course pays the bill, for the ore has to stand the costs of weighing, sampling and assaying in South America, which are higher than at a smeltery in the States.

A frequent source of trouble between ore buyer and miner is the moisture. The Chilean who mines from a desert region cannot easily be made to believe that a deduction from gross weight for water is just, although he will agree that the chemist that determines the metal contents should dry the sample with great care before assaying. Ore apparently as dry as a bone will frequently contain up to 1% moisture. A 100-ton lot, therefore, will contain one ton of moisture. If the ore assays 25% copper, the loss, if moisture is not deducted, amounts to $90 on the lot. All ores contain moisture, but if the shipper notices dust arising from a heap that is being moved or crushed, it is difficult to convince him that water is present in the interstices of the ore. A test is the only recourse, and the inexperienced bewail the loss of time and the expense which such a test entails.

The ore buyer is also up against the peculiar condition that he must give way to the seller on the subject of umpires in South America. When differences arise between analyses of buyer and seller, it is customary to submit the dispute to an umpire in the country. The ore buyer is practically certain to lose the case. My experience extending over years shows that on settlements, where an umpire is called in, payment is made for greater value than can be found in either the United States, Great Britain or Germany. This does not imply that the methods of determination in South America are unfair. The simple fact is that determinations made there are scientific investigations, whereas in this country and in Europe determinations for the values of metals in ores are looked upon as commercial assays.

In this country and in Europe when an umpire reports results that do not check within reasonable limits, his name is stricken by mutual consent from the list of umpire assayers. In South America the number of assayers competent to make reference assays is so limited that even though they may show tendencies to be marked by high or low in their reports of percentages present, they cannot be dropped, because there is no one to substitute for them. In assaying for silver it is universally understood that a weighed amount of ore be fluxed with test lead in a scorifier, subject to an oxidizing atmosphere at a low red heat to slag off the impurities of the ore; the lead button formed, when freed from adhering slag after cooling, is cupelled, and the resulting silver bead, when cool, is weighed and the percentage of silver determined. In South America some umpire assayers correct this result by scorifying and cupelling the slag and cupel from first operation, thereby obtaining a higher result than the commercial.

Diplomacy Required of Ore Buyers

The successful ore buyer in South America becomes the friend of the miner and works for his advantage. Firstly, because he is usually ambitious and wishes to secure as large a tonnage of ore as possible. Secondly, because he wants to keep busy, which makes him restless and always scheming how he can increase the volume of his business and incidentally help his friend, the miner. Thirdly, he is so far from his home office that it is more agreeable to be friendly with his neighbor than to court favor with the smelter for whom he works. He must do business with all sorts and conditions of men in South America, as in any other country. The ore buyer representing Northern and European smelters is not in a position to compete against unfair practices. The standing of his foreign connection forbids such a course, even though convinced that he is dealing with unscrupulous people. As a rule he cannot compete under such conditions and must leave such trades to small local concerns which are not as jealous of their reputations and not held down by strict rules from their principals.

Above all the ore buyer must avoid lawsuits, and he will therefore make concessions in South America that he would not make at home rather than face a legal controversy. Very often a deal in ores is arranged over a friendly glass, and both parties are willing to settle difficulties by argument as they arise.

Mechanism of Chile Bar Sales

Jackson Brothers, in Valparaiso, who handle the Chile bar business, are advised by the Chilean smelters in the early part of the week that a certain tonnage of a certain brand of bar is to be sold for delivery at port, shipment to be ready on a fixed date. Jackson Brothers then notify the prospective bidders that one or more parcels will be sold to highest bidder at 5 o'clock on a fixed date, usually on a Thursday or Friday. The bidders send in their offers in sealed envelopes, all of which are opened as the clock strikes 5, and the award is made to the highest bidder. The price is in Chilean pesos per metric quintal of bars.

Jackson Brothers issue copper statistics from which they in turn calculate the value of copper ores. The basis for quotations is the price realized for Chile bars at auction. This price takes account of London copper quotations, sterling exchange, freight rates, war risk, insurance, etc. The Chileans subscribe to the publication, and the ore buyer for a North American concern ofttimes is forced, in order to meet the competition of local smelters, to buy upon these so-called quotations. In so doing he takes a risk upon varying factors, which he would much prefer to avoid.

Ores carrying tin, bismuth, vanadium, molybdenum or tungsten are rarely bought in South America on weights and samples taken in the country, for the miner is not so familiar with these ores as with ores of silver, lead and copper and therefore prefers that they be sampled in Europe or the United States. The ore buyer in treating for such ores arranges that they be sold to best advantage by his principals, and for the trouble of arranging a shipment covering insurance, freights and a market in the North, he charges a commission and also charges all expenses pertaining to that shipment.

In South America a business friend is usually a staunch friend and will not change to a competitor or make shipments direct without giving fair warning. When such changes occur, the reason is to be sought in some trivial misunderstanding or some delay. Frequently assays do not arrive in the hands of the ore buyer as soon as the miner believes they should, or cables giving quotations sometimes are delayed, etc.

Mining and marketing of ores being new to the South American, the producer frequently does not seek the best price he can obtain, as he would in the North, but leaves the matter of marketing to his banker or a commercial friend, and for this reason the ore buyer must carefully scan the local papers and inquire regarding developments in the whole South American Continent, in order to be the first on the ground when a strike is made and interest the miner in his behalf. Like the commercial traveler he must return from time to time to the producer to learn what is going on. He must be a good mixer, a good story teller, have a copper-lined stomach, an iron constitution and above all be a gentleman. He must mingle in government circles, with bankers, know where he can obtain advantages in exchange, and be kept informed of impending changes in governmental or mining laws. He must be a reception committee for all visiting mining engineers, a translator for foreigners and a diplomat.

During the last 15 years conditions of production in South America have changed materially and, as stated, the disposition of the product has undergone tremendous changes. The auctions at Valparaiso for Chile bars have become less frequent, because a good many of the Chilean copper smelters have contracted their product on annual contracts to the States. Besides, keen competition of the North American smelting plants has put some of the Chilean smelters practically out of business or at least reduced the amount of ore that they can treat to advantage. Four large smelting concerns in the United States have constantly drawn supplies in ever-increasing quantities from South America: On the Atlantic coast the Nichols Copper Co., the American Smelting and Refining Co., and the United States Metals Refining Co.; on the Pacific coast the American Smelters Securities Co. These concerns have established their own buying agencies in South America. The group connected with the American Smelting and Refining Co. has also developed large copper properties.

The production of copper in Chile has steadily risen and in the year 1913 reached 39,400 tons. Peru, which in 1902 produced 7,600 tons, reached a production of 25,700 tons in 1913. A list of the production of copper in South America and the quantities imported into the United States is appended hereto. It will be seen that the bulk of the product is now going to the United States.

Since the outbreak of the war this situation has been accentuated and a change has taken place in regard to the methods of ore buying, both for financial and market reasons. The use of the sterling draft has become less universal and the quotations published in New York have become more acceptable to the South American producer.

A Forecast for the Next Decade

In conclusion an attempt will be made to forecast the developments for the next decade. As previously stated, the competition of the refining and smelting plants in the United States has reduced the business of the local smelters to the treatment of comparatively low-grade ores that cannot stand the cost of transportation, although the grade of the ore varies with the price obtainable for the material; but strange as it may seem and in spite of the high freight rates, the smelters in the United States can generally compete successfully against the local smelters for any copper ore containing more than 15% copper, because cost of coke, inefficiency of labor and small tonnage make the operating costs of local smelters very high. The Panama Canal is going to further this trend, and the result would have made itself felt ere this, had it not been for the high freight rates that developed as one of the results of the war.

Furthermore, there is one difficulty standing in the way of the establishment of a highly developed plant in South America for the treatment of all kinds of ore, and that is the lack of a proper smelting mixture. Especially in Chile, difficulty is being encountered in securing an ample supply of basic sulphides, which are the necessary foundation for large smelting enterprises. There can be no question, however, that in a relatively short period, owing to the more intensive mining developments, a discovery of sulphide ores at the lower levels will be made in such tonnages that the erection of a modern and uptodate smelting plant will become profitable. Large interests in this line in the United States will doubtless develop such smelting enterprises. Even when these conditions arise, South America will continue to be an exporter of ores and minerals for a long time on account of the difficulty of centrally locating a comprehensive smelting plant.

Some beginnings of successful smelting enterprise have been made. The Backus & Johnston Co. at Casapalca, Peru, has developed during the last few years into a very successful smelting company. Conditions at the new plants of the Chile Copper Co. and the Braden Copper Co. in Chile as well as of the Cerro de Pasco company in Peru are entirely different, because these enterprises are principally, if not entirely, confined to the treatment of their own ores.

SOUTH AMERICAN COPPER PRODUCTION IN METRIC TONS

	1912	1913	1914
Bolivia	4,681	3,658	2,743
Chile	39,204	40,195	40,876
Peru	26,483	25,715	23,647
Copper imported from Chile to the United States	16,135	19,785	24,661
Copper imported from Peru to the United States	19,905	19,350	20,176

There is no doubt that the mineral wealth of South America is an ever-growing factor for the markets of the world and that North American methods are becoming more and more acceptable. This has been proved by the developments of the last 25 years and is evidenced by statistics; in 1913 (the last year of normal conditions) out of a total world's copper production of 993,000 tons, about 715,000 tons were brought to the market as refined product through the United States. In other words, 72% of the world's copper production was smelted here, although the mines located in the United States produced only 55%.

Caceres District, Colombia

Negotiations have been in progress lately for the transfer of the Vargas mines in the District of Caceres, Department of Antioquia, Colombia. There has been considerable hand-washing along Caceri Creek during the present season; on the Farley placer two giants have been at work with good results, and some work was done on the lode mine of Robert Farley in the same valley. On Tamaná Creek two monitors have been working on the central claim of the Tamaná Mining Co. Some exploration of placer ground was in progress in this region last year for North American interests.

Metallurgy of Native-Silver Ores of Southwestern Chihuahua*

By W. M. Brodie†

SYNOPSIS—Mines worked prior to 1632 in neighborhood of Batopilas. Ancient ores carefully hand sorted and smelted in the vaso. Native silver found in fissure veins in diabase. In coarse-grained rock no native silver has been found in commercial quantity. Occasional small amounts of argentite and ruby silver are found. Present milling comprises concentration, amalgamation, cyanidation and smelting. Product of mine often being shipped as bullion within 48 hr. of blasting.

Nearly three centuries ago the ores of native silver of southwestern Chihuahua drew the attention of the Spanish *adelantados,* or "advance guards," who explored and opened up for settlement new country in what is now northern Mexico. These military explorers were either accompanied or closely followed by prospectors, who were willing to run risks and endure all kinds of hardships and who seem to have been quite able, when they found good ores, to open up mines and extract the valuable metals. The more one sees of what they did, the more one has to admire their resourcefulness and the wonderful results they were able to obtain. With iron costing one ounce of silver per pound and steel several times as much, at a distance of thirty-odd days' hard continuous travel or 150 days' muleback freighting from Mexico City, they worked mines in the inaccessible mountains, overcoming all difficulties. In a deep gulch on the western slope of the Sierra Madre the ores of Batopilas were discovered about the year 1632, and it is probable that at that time there were already being worked in the mountains of Sonora and Chihuahua a number of mines which later became important. An old document connected with a lawsuit about the ownership of mining property in Topago, on the Chinipas River, which falls into the Fuerte some distance below the junction of the Batopilas and Fuerte Rivers, mentions a few years later that there were at that time in that neighborhood "five 'dones' who knew how to sign their names," or in other words, five educated Spaniards.

In those early days and much later, ores were always enriched as much as possible by careful hand sorting and washing and were then roasted and smelted with litharge in the inclined throat of the *vaso,* or small cupellation furnace. The lead ran down on the hearth and was cupelled in the usual way; the slags from the *vaso* were smelted subsequently with the surplus litharge from the cupellation in the small Spanish shaft furnace. Both furnaces were built of sun-dried brick and are still being used in many places.

Sorting, Testing and Concentrating the Ores

The sorting of ore was a profession, and the sorters grew very expert at the work and recognized the smallest speck of rich mineral instantly, even when working at full speed. The prospector also had many little tricks to detect metals. His great reliance was of course the horn spoon, in which he concentrated and washed his samples, but he tried the malleability of grains of argentite and horn silver with his teeth, and he knew that silver salts have a peculiar sweet taste, that silver when volatilized gives this same taste and a sweet smell and that a doubtful grain of mineral if placed upon the burning end of his big cigarette of *macuche* tobacco, when the smoke was inhaled, would show by the taste whether it was silver or not.

LOOKING DOWN BATOPILAS RIVER FROM ABOVE SAN MIGUEL MINE

The ordinary cobbing and sorting table at the mines was generally a considerable distance from water. The usual construction was as follows: A small hole was scooped in the ground, preferably on the edge of the dump and lined with stones embedded in clay so as to form a basin about 2 to 3 ft. in diameter. On opposite sides, two flat stones were placed with a slight inclination toward the basin. These served as anvils and washing tables on which the ores were broken, cobbed and wetted with the hand, the water draining back into the basin, which was

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water-tight as long as it was kept full and the clay was kept moist. This also saved the fines, which were afterward concentrated in a wooden pan. The consumption of water was very small, as only the doubtful ores were wetted for identification. Millions of tons of ore have been concentrated in this manner.

Ancient Smelting Methods

The *vaso* was a small reverberatory furnace. It is still used in many places. The fireplace sometimes had a grate, but usually it had not. Dry and resinous woods were used as fuel. The flame passing the fire-bridge slanted down to the hearth, which ran across the furnace and in the ordinary furnace rarely measured more than 3 ft. by 2 ft. and often less.

From the hearth the flame passed slanting upward through a long throat, generally 12 to 15 in. wide, to the outlet or chimney, at most a couple of feet high. The ores were fed in with the necessary fluxes through an opening or door on the side of the throat, and when the bath in the hearth had been cleaned from slag the blast from a hand-bellows was blown in from one side and the litharge was drawn off at the other. The bottom of the hearth was made of wood ashes and clay, and an expert *afinador,* or cupeller, knew how to repair the hearth and to build up a new breast while the furnace was hot, so that operations could be repeated a number of times after the silver was taken out of the furnace.

No iron was used about the furnace, and often the whole smelting and refining operation was done without any iron tool of any kind, a crooked stick of a kind of wood that burns only very slowly being generally used to skim the bath. Later the *garrapata* was used—an iron tool with a cleaver's blade on one end to cut and shape the breast of the furnace and a hook on the other to remove lumps of hot litharge and slags.

The *horno de fundicion,* or shaft furnace, was generally built, for purposes of strength, in an adobe wall. In size it was limited by the wind, or blast, furnished by the bellows, worked by hand and generally of one-man power. At the level of the tuyere it generally had an internal cross-section 12 in. in depth by 9 in. in width, the height of the furnace proper above the tuyeres being about 5 ft. 6 in.

Generally the pot, or hearth, was made outside the furnace, the lead bullion being tapped off from the bottom into sand molds. It seems that only very rarely a forehearth was used communicating with the inside of the furnace. The tuyere in a properly appointed furnace was generally a copper casting, so heavy that it was not melted by the blast. In this the two nozzles of the double hand bellows rested.

The great requisite in smelting, both in the *vaso* and in the shaft furnace, was to have an easily fusible mixture, from which all "rebellious ore," especially zinc ore, had been separated as much as possible. Many men were very skillful smelters; still, a successful smelting operation needed much preparation, great care and constant attention.

When the rich native-silver ores were discovered in Batopilas and it became known that they could be smelted by anybody in any ordinary forge by simply placing a little earthen dish below the blast hole and building the fire over it, the fact drew much attention, as the cakes of silver produced were very pure and were accepted anywhere as money. This was a great attraction and helped greatly to draw prospectors to the new camp.

Up to this day a considerable amount of silver is produced in this same way, a little litharge generally being mixed with the ore so as better to gather the smaller particles of silver. Many of the stores in Batopilas sell the earthen dishes and the litharge over the counter to the customer, who can then have a forge for his convenience in the back yard, where no questions are asked.

Occurrence of Native Silver

The native silver in southwestern Chihuahua is found in fissure veins that run through an augitic rock, classed as diabase.

This rock is found in a few gulches and valleys where erosion has removed the superimposed layer of porphyritic rocks that form the sierra. The diabase is younger than the granite which is often found near it, because the granite is sometimes found in it as boulders and it is older than the porphyritic rock, which is often found in it as veins or roots.

Batopilas and Morelos have both been famous for their rich ores; San Joaquin, el Realito and los Cueros have yielded ores of native silver, but never enough to make these places famous.

In the valley of Batopilas the diabase is exposed in an area about 2 by 4 mi., but not all the diabase is the same. There seem to have been various flows, separated by long periods but forming a fairly continuous body. The texture of the rock also differs. Most of the diabase is rather coarse-grained and shows plainly the crystals of augite and feldspar; another part is fine-grained. Sometimes it gets to be aphanitic in texture, especially near the contact with the porphyritic rock.

It is a well-known fact among the silver miners in Batopilas that in the coarse-grained rock no native silver has been found in commercial quantity. The rock shown as *buen panino,* or promising ground, is always fine-grained and generally contains a considerable amount of impregnated pyrites.

There are in Batopilas diabase three classes of veins. The oldest are well defined, but have a filling of dead rock that shows no mineralization such as generally occurs in ore veins. The second class of veins shows life; that is, they have a vein filling that occasionally shows quartz, calcite, blende, galena and arsenical pyrites. It is in these veins that the native-silver ores were formed and are found, but the native silver was a later deposition than the base ores with which they are associated. The silver was deposited near and sometimes in the minerals mentioned simply because the ground was not so firm there. A third and younger set of veins had a vein filling consisting mostly of ground-up country rock with now and then breccia of mineralized vein matter, a part of which seems to have belonged originally to veins of the second class. Among this vein matter there has been found native-silver ore in some quantity, but this ore, which sometimes is in lumps worn round by rolling motion, evidently was formed somewhere else.

Native silver has been found both with quartz and with calcite, but the silver miner prefers to see a basic vein filling. In depth the ore is generally more acid than in upper levels. Galena, blende and iron pyrites, when they are free from metallic silver, carry only about 3 oz. silver to the ton, and therefore in a place like Batopilas or

Morelos—12 to 20 days' freighting from the railroad—the base ores have no commercial value.

Occasionally in the silver-bearing veins a small amount of black silver (argentite) is found crystallized and sometimes a very little arsenical silver (ruby silver), but the latter is not of commercial importance.

There is this peculiarity about the native-silver ores—they come in spots and are very rich, sometimes as lumps of solid silver. Generally, however, the silver is crystallized in the form of nails or as leaves and ferns, and sometimes it is very finely divided. In the neighborhood of these rich spots there generally is a more or less extended zone of good ore and medium-grade. Beyond this, the vein matter, if it contains silver at all, is generally very low in grade. It would not pay to mine this low-grade ore if it were not for the fact that the poor ore often serves as a guide and leads to richer spots. The mines therefore produce a small amount of rich and a large amount of very poor ore—so poor that often it is a question whether it shall go to the mill or to the dump.

The facts that the concentration mill is situated at the mouth of one of the main tunnels, that the other main tunnel is connected with this mill by an aërial tramway, that the machinery is driven by water power and that the ores can be concentrated 50:1, make it possible to mill very low-grade ores, but it makes the question of economical milling very different from that in other places, as some of the assays given below will show. In 1880, when ex-Gov. Alexander R. Shepherd, of Washington City, formed a New York company and bought the mining property of the Batopilas Consolidated Mining Co., the native-silver ores were being worked both in Batopilas and in Morelos as follows: The ores were carefully sorted by hand cobbing and divided into rich ore and poor ore, but nothing was considered worth keeping which did not show silver or black silver in the horn spoon. The saying was, "Silver or nothing." The rich ore was crushed either by hand or in a small stamp battery, and the native silver and black silver were sifted out dry or washed out by hand and smelted. The tailings from this washing, together with the ores of second grade, were ground to a pulp in *tahonas de arrastre,* or stone drag mills, driven by the impact of a stream of water. When the ores were sufficiently ground, mercury was put into the *tahona* to gather up the fine silver, and when a washed sample showed that no free silver was left, the *tahona* was slushed out and the residues were washed by hand.

The heavy residues from this washing, consisting mostly of galena and pyrites, with fine black silver, were smelted in the *vaso,* and the litharge and other products were smelted in the shaft furnace in the usual Mexican style.

Governor Shepherd found that the vein matter that was thrown on the dump contained a small amount of silver, partly in the form of fine metallic and partly as fine black silver, and that these minerals, when the ore was ground, were flattened out and could be saved by concentration. A stamp mill therefore was erected, and it was found that the concentrates on the average amounted in weight to about one-fiftieth of the ores ground, and furthermore that the concentrates by careful reconcentration could be separated in two classes—one, high grade rich in metallic silver, and the other of much lower grade containing finely divided black silver.

Amalgamating pans were therefore used to collect, with mercury, the silver from the products containing finely divided native silver; the other concentrates were roasted and leached with hyposulphite of soda. The latter process gave an extraction of about 85%, but was expensive because firewood for roasting was scarce and the salt had to be brought on muleback from the coast, which took 24 days' freighting. Therefore, when the cyanide process found general acceptance, the milling process for the low-grade ores was changed and is now used in Batopilas, as follows:

The ores are crushed in a stamp mill, and the coarse native silver is taken out of the mortar. The pulp of the rich ores, which passes through the screen, is treated in amalgamating pans with mercury; the pan tailings are treated with cyanide solution during agitation. The pulp of the low-grade ores is concentrated on shaking tables, the tailings go to the river. The concentrates are reconcentrated; the richer part, holding native silver, is treated in the amalgamation pans like the high-grade ores; the poorer parts of the concentrates are leached with cyanide solution by percolation.

SAN ANTONIO 100-STAMP MILL

The enriching of the good ore begins as soon as it is discovered in the mine. The rich ore is first uncovered; that is, the poor ground is blasted away, so as to leave what may be called the pay streak standing intact. This is called the *desmonte.* The working is then cleaned out, and the rich ore is shot down separately in the presence of the mine bosses, who, after blasting, pick up the rich ore with a few trusted men, see it sacked and accompany

it until it is stored in a safe place. The remainder of the ore broken down is then brought out to get a special revision outside.

The high-grade ores are weighed at the mine, carried under guard to the mill for rich ores and reweighed there. Some of the ore may be massive silver, sometimes the silver may be as fine as hair. When a mine is in bonanza, the first-class ore often averages one ounce of silver to the pound of ore.

Delivered before the small stamp mills, specially arranged for the purpose, the rich ore is first broken with the sledge and the richer pieces separated. It is then fed by hand, the poorer part first and the richer part at the last. The fines pass through the screen, the coarse silver remains in the mortar. When the silver has been pounded sufficiently clean by the stamps, it is taken out of the mortar to the silver room to be washed by hand to free it from pieces of rock and heavy concentrates with which it may be mixed. As the native silver is generally crystallized silver and almost chemically pure, the washed stamp-mill silver runs over 900 and often 950 fine and is ready for the ultimate refining.

Treatment of Stamp-Mill Fines

The fines from the stamp mill containing all the fine silver that passed through the screen (ordinarily 30-mesh) are taken to amalgamation pans where they are ground in a 0.5% cyanide solution, and after they are sufficiently fine they are treated with mercury to collect the metallic silver. The amalgamation period is made as short as possible so as not to dissolve much mercury in the cyanide solution. The time required depends on the quantity of silver present and on the heavy minerals that are with the ore. The resulting amalgam is washed, and the pan tailings, separated in the settler, go to a Dorr thickener and from there to small Pachuca tanks 7 ft. in diameter and 30 ft. high, where they are agitated by compressed air in a 0.5% cyanide solution. The pan tailings of rich ores, when they leave the settlers, often hold not more than 15 oz. per ton, but this depends on the ore and especially on the amount of black silver present. Generally they run 30 to 40 oz. per ton.

The heavy part, which concentrates in the settlers and contains galena, blende, pyrites and sometimes black silver, is washed to separate the mercury, the washings going to the percolation tanks to be leached with cyanide solution. As the silver ores in Batopilas, with a few notable exceptions, hold no copper and as the base sulphides contain no combined silver in commercial quantity, the process is simple.

The amalgam is washed, squeezed and distilled in the usual-style retort. When the ore is rich, the amalgam may be as high as one-third silver—that is, the silver may simply be held together by a coating of amalgam; when the ores hold little metallic silver, the amalgam may contain only one-fifth of silver or even less. The crude-retort silver generally runs 950 fine or over. Its purity depends on the care with which the amalgam has been washed.

The concentration of the low-grade ores, which formerly were discarded, has become quite important. In the last few years the silver from the low-grade or concentration ores has amounted to about one-third of the total production, but when the mines happen to be in silver they are much less in proportion.

When rich ore is struck in a mine, the work is concentrated there so as to get the silver out and away as soon as possible. The low-grade ores then are richer than usual and may run up to 15 or even 20 oz. per ton, but under average conditions and with careful work in the mine they should not, and seldom do, run this high. If they do, the reason why has to be investigated, for fear that the rich ore, which needs guarding, is not getting the necessary care. In the month of June, 1915, for instance, the assays of the Batopilas company show that the low-grade ores from the San Miguel Tunnel group ran 10.6 oz. per ton; from the Porfirio Diaz Tunnel group, 9.34 oz. per ton; and in the month of July, 10.1 oz. per ton and 10.50 oz. respectively.

The tailings of the first concentration on shaking tables of the Bartlett and Wilfley type in the month of June from the San Miguel Tunnel group ran 2.15 oz. per ton; from the Porfirio Diaz Tunnel group, 1.94 oz. per ton; and in the month of July, 2.13 oz. per ton and 2.04 oz. respectively; giving an extraction into the concentrates of 76.6% in June and 75.7% in July.

The tailings from the concentrators, reconcentrated, gave a small amount of concentrates assaying only 30 oz. per ton. The concentrates after reconcentration assayed: In June, first-class concentrates, 4,128 oz. per ton; second-class concentrates, 227; in July, first-class concentrates, 3,605 oz. per ton; second-class concentrates, 203. There was a small amount of third-class concentrates, 90 oz. per ton more or less, and tailings averaging between 8 and 9 oz. per ton.

The rate of concentration was about 50:1, and the first-class concentrates contained, chiefly in metallic silver, in ounces, about as much as the total amount of the concentrates of lower grade.

Grades of Concentrates

The mines at the time were not in good silver, and on account of the revolution the working force was much reduced. Under ordinary favorable conditions the rich concentrates run up to 6,000 and 7,000 oz. per ton and the second-class concentrates often as high as 300 or 400 oz. By a simple treatment with cyanide solution and careful decantation in an amalgamating pan and the use of mercury, inside of a week these rich concentrates have been reduced in value to less than 30 oz. per ton. They were then turned into the Dorr thickener together with other pan tailings.

The second-class concentrates treated by percolation in a stone tank have sometimes dropped in six weeks to 5 oz. per ton. One lot of concentrates, assaying over 300 oz. per ton, was used as a filter for clearing the cyanide solution before the precipitation of the silver, and when it was removed it assayed only $\frac{3}{10}$ oz. per ton. This of course is exceptional and commercially of little value, but it shows how well sulphide of silver, as it occurs in concentrates, can under favorable conditions be dissolved by a cyanide solution.

The silver is precipitated from the cyanide solution with zinc shavings in the usual way. At one time there was considerable trouble in working up the shorts and in keeping zinc out of the precipitate. It was found that fine shavings of soft zinc gave the smallest amount of shorts. By using a fine screen when washing the precipitate out of the zinc shavings, avoiding unnecessary friction, and by making the rich solutions pass up through

trays covered with layers of zinc shorts, it was found possible to avoid accumulation of shorts. With care the precipitate can be made 750 fine; in July, 1915, the precipitates were 666 fine.

The second-class concentrates are leached in stone tanks, and together with them all the coarse settlings or concentrates from the settlers in which the pan tailings are washed after amalgamation, after the amalgam has been separated from them by hand. These washings hold from 200 to 400 oz. per ton, mostly in the shape of black silver. There is only a small amount of this silver sulphide produced, and generally the silver is fine enough to be extracted by cyanide solution.

In June and July of this year the second-class concentrates, from which the native silver was removed by reconcentration, held over 200 oz. per ton. In fine metallic silver they held 10 to 25 oz. per ton. This silver leaches out slowly, but without difficulty. The assay sheets for July, 1915, show that the charge in tank No. 1, in which similar material was being leached, which originally held 240 oz. per ton, was as follows:

July 6, 8.2 oz. per ton, of which 0.20 oz. was metallic silver
July 13, 6.6 oz. per ton, of which 0.20 oz. was metallic silver
July 19, 4.1 oz. per ton, of which none was metallic silver
July 30, 3.8 oz. per ton, of which none was metallic silver

The tank was then discharged.

The tailings from the settler under the amalgamation pans, which pass through the Dorr thickener on their way to the Pachuca agitators, generally hold less than 40 oz. per ton, and when discharged from the Pachuca tanks they held according to the assay sheets:

July 2, discharge from Pachuca tank No. 1, 4.5 oz.
July 17, discharge from Pachuca tank No. 2, 4.2 oz.
July 28, discharge from Pachuca tank No. 1, 4.4 oz.

The discharged pulp passes through a suction filtering tank to have the solution removed before it passes to the river. The discharge from the filter, corresponding to the foregoing, assayed:

July 3, tailings discharged from the suction filter, 4.5 oz.
July 18, tailings discharged from the suction filter, 4.1 oz.
July 29, tailings discharged from the suction filter, 4.1 oz.

As these are tailings from very rich ores, they do not represent a large quantity.

Silver-Refining Methods Employed

The washed precipitate after filtration is thoroughly dried in a cast-iron retort. It is then refined together with the stamp-mill silver and the pan silver in a reverberatory silver-refining furnace of the Freiberg type, with movable hood. The hearth is made either of wood ashes and clay or of brasque (three parts coke powder to one part of clay), according to the amount of fluxing that has to be done in the furnace and the number of charges that the bottom has to stand before renewal.

The coke and clay bottom is by far the safer and more refractory, but the sulphur that the Mexican coke contains makes the refining of the silver to over 999 fine somewhat slower.

The pan silver and the stamp-mill silver are charged first. This holds a certain amount of silica, and when this floats on the bath, the precipitated silver from the cyanide process, mixed with about 5% of borax glass, is put on and allowed to melt. The silica from the ore, together with the sulphides from the base ores contained in the pan silver, make, with the borax and the impurities of the silver from the cyanide silver, a fairly fusible slag, which is skimmed off with a wooden skimmer when sufficiently liquid. To make the slag liquid so that the metallic silver may liquate from it into the bath underneath, a high heat is required, but this can safely be given as long as the bath is covered. When the slag is liquid, the temperature is lowered to facilitate skimming and to prevent undue volatilization. The impurities of the bath are principally sulphur from black silver and base sulphides, arsenic from arsenical pyrites, a small amount of mercury which has been dissolved by the cyanide, and zinc. With the help of metallic iron the sulphide is made into a matte, and with a light blast of air over the bath the zinc is oxidized.

If the bath is kept at the proper temperature, there seems to be no great loss of silver by volatilization. The white fumes coming off the bath contain little silver; only when the heat is too high or when the silver reaches purity and the fumes become purple or, by too high a temperature, green, is there a considerable loss. With care, however, this can be avoided. The silver is ladled out of the furnace into greased molds with the usual precautions against spitting.

The refining slags are ground, the metallic silver is sifted out, and they are then treated in an amalgamating pan with cyanide solution and mercury in a manner similar to that used for the high-grade concentrates. This process avoids byproducts and cleans up the operation quickly.

At the Batopilas mills the management tries to work up and to clean up completely each month, though during the troubled times of the revolution this has not always been possible.

The Mexican miner or millman has great powers of quick observation. Brought up to the business, he is very quick in recognizing silver either in the rock or anywhere else. This is a great help in many ways. The best operator or prospector in the silver mines of Mexico is the man who knows best how to make use of the local talent. On the other hand, this same talent has some disadvantages, especially in times of revolution. That the companies operating of late years have suffered from this talent to their sorrow need not be told here. Exploring for silver, hope deferred often makes the heart sick and the belly empty, but when a mine is in bonanza and the ores are rich, it is very satisfactory to see 75% of the metallic contents which are blasted down in the mine only this morning shipped in the shape of bars before dark tomorrow. Many times has this happened in years gone by.

The Monroe Doctrine a Pan-American Doctrine*

This Pan-American congress may prove to be the most important Pan-American gathering that has been held in the history of the American republics. It has come at a critical time in world development, and the eventual practical results which should follow its deliberations and conclusions may determine the sovereign integrity and actual life of all the American republics. The spirit of fraternity, solidarity and common interest which is inspiring all the delegations that are here assembled is giving a meaning to Pan-Americanism which all of the nations must forever hereafter respect. While there is

*Excerpt from speech by John Barrett, director general of the Pan-American Union and secretary general of the Second Pan-American Scientific Congress, Dec. 31.

nothing in the word or spirit of this congress which is in any way antagonistic to Europe, it will be unquestionably a most powerful factor in cementing that new relationship of mutual interest and interdependence which has been growing with great rapidity in the last few years.

In the minds and thoughts of everybody interested in Pan-Americanism is the question, What is going to happen to Pan-America when this war is over? Immediately and instinctively there is the reply, The American republics must stand together for the eventualities that may possibly develop. While everyone would deplore any agitation or suggestion that a European nation or a group of European nations, following this struggle, should undertake any territorial aggrandizement in the Western Hemisphere or in any way take action that would contravene the Monroe Doctrine, it must be borne in mind and cannot be for a moment overlooked that whatever way this war results there may be little or no love for the United States and the other nations which form Pan-America. Whichever group of nations wins in this mighty combat will say that it won in spite of the attitude of the United States and the other American republics. Whichever side loses will say that it lost because of the attitude of the United States and its sister American republics.

No matter, therefore, how just and fair the nations of America may have been in their efforts to preserve their neutrality and in no way interfere on either side of this conflict, the war passions and the war power of the peoples and the governments of the victorious group of nations may force a policy toward Pan-Americanism, toward the Monroe Doctrine and toward their relationship with individual countries of the Western Hemisphere, which will demand absolute solidarity of action on the part of the American republics to preserve their very integrity.

In the light of this terrible though regrettable possibility, one supreme thought stands out, and that is: If a foreign foe were to succeed in destroying the sovereignty of the United States, it would only be a question of time when that foe would destroy the sovereignty of every other American republic. In turn, there is no doubt whatever that if any foreign foe ever succeeded in extending its dominion over a considerable part of Latin America, and if the nations of Latin America should become dependencies, it would inevitably follow that the United States would meet the same fate, because no foreign foe could achieve such a result except by victory over the United States.

All Pan-America will therefore rejoice if this conference shall give the inspiration (though it may not be able to write the act, because it is not a political gathering) for the actual evolution of the Monroe Doctrine into a Pan-American doctrine, which will mean that the Latin-American republics, in the event the United States were attacked by a foreign foe, would, with all their physical and moral force, stand for the protection and sovereignty of the United States just as quickly as the United States under corresponding circumstances would stand for their sovereignty and integrity. With such a Pan-American doctrine recognized and approved by all the American republics, there would be no danger for the sovereignty and peace of Pan-America, and the greatest step possible for practical peace among all nations would be achieved.

Coal-Dust Firing in Reverberatory Furnaces*

By C. R. Kuzell†

SYNOPSIS—Coal-dust firing of reverberatories adapted from cement-kiln firing practice. Grade of coal permissible is not fixed by close limits. Coal must be dried sufficiently so that it will be easily suspended in the air blast, but not dry enough to make spontaneous combustion likely. Coal is pulverized so that 90% will pass 100- and 80% pass 200-mesh. Blast pressure varies from 8 to 16 oz. per sq.in. Furnaces of capacity 400 to 700 tons ore per day burn 60 to 100 tons of coal dust. Improved new charging methods which largely obviate fettling and necessitate relocation of matte-tap holes. Furnace repairs reduced.

Much has already been written on the subject of coal-dust firing in reverberatory furnaces for the production of matte, hence this further contribution to the literature will be more or less of a summary of descriptions and facts already published.

Proposals for the use of powdered coal as a fuel date back many years. Professor Hofman, in his "General Metallurgy," states that the first experiments were made by Niepce in 1818. Attempts to use it in boilers and furnaces of various kinds were recorded over 40 years ago. In 1895 the Atlas Portland Cement Co. began the successful use of coal dust in firing cement kilns. The success is attributed to the work of Messrs. Hurry and Seaman, who began their experiments in 1894.[1] The success of the cement people was not entirely overlooked by copper metallurgists in the first few years of its established use, for the files of the copper companies are found to contain matter pertaining to the possibility of the use of pulverized coal in reverberatory furnaces, dating back to 1902. However, the first recorded application of this method of firing to reverberatory furnaces did not come until 1905, ten years after its successful use in cement kilns, and even then its success was doubted, so that it did not become established practice until 1911.

In 1905 Mr. Sörensen[2] equipped a 38x15-ft. reverberatory furnace for coal-dust firing at the Highland Boy smeltery, Murray, Utah. The furnace was small compared to those now in use, and the coal preparing and feeding equipment was such as we would now designate as

*Paper presented at Second Pan-American Scientific Congress, Washington, D. C., and published by permission.

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[1] "Pulverized Coal in Cement Industry," by R. C. Carpenter, "Journ. A. S. M. E.," October, 1914.

[2] "Coal-Dust Firing in Reverberatory Matting Furnaces," by S. Severin Sörensen, "Eng. and Min. Journ.," Feb. 10, 1906.

inadequate properly to prepare and feed coal dust. Mr. Sörensen naturally encountered difficulties, but none of them seemed unsurmountable, and his results were good in that he was able to increase the furnace capacity 30% and to make a 24% reduction in the fuel required to smelt one ton of charge. His conclusion was: "It is certain from the tests made, that this system of firing is capable of very efficient results in reverberatory smelting in a plant properly laid out and equipped for the purpose."

In 1907 Mr. Shelby[3] fitted up a 100x19-ft. furnace for dust firing at Cananea, Mexico. His equipment was also much inferior to that of present-day practice. He likewise had a series of difficulties to overcome, but had apparently got the best of them when his work was terminated by a general shutdown of the Cananea works. When smelting operations were again resumed, the company was able to make a very advantageous contract for oil fuel and the proposed coal-dust firing was therefore dropped. However, Mr. Shelby saw that the method could be successfully applied, and his conclusion was: "We are convinced that when the furnace has been reconstructed to meet the required conditions, we shall get excellent results with this method of firing; even with the coal that we use here, we expect to operate the furnace with less than one ton of coal to five tons of flue dust smelted and consequently to obtain a far greater calorific efficiency of the fuel in the furnace than possible with the old method and, *ipso facto,* less waste heat with which to generate steam."

In December, 1911, David H. Browne[4] put into commission a coal-dust fired reverberatory 112x19 ft. at the Canadian Copper Co.'s plant at Copper Cliff, Ontario. His coal plant and coal-dust feeding plan were well designed, and the furnace was a success from the start. This installation marked the beginning of the new practice of firing with coal dust. At the present time several large copper-smelting works are using coal dust in their reverberatory furnaces with excellent results. An enormous installation (with a capacity of 1,000 tons of coal per day) has been made at Anaconda, Mont., and equipments of lesser importance have been made at Great Falls, Mont., and Garfield, Utah.

Figs. 1 and 2 show a flow sheet and plan of the Anaconda installation.

Grades of Coal Permissible

The grade of coal that can be successfully used in firing reverberatory furnaces is not fixed by close limits. Indeed, vastly different coals can be used. Unless there is something detrimental in the ash of coal that would make it difficult to handle when it forms accretions in the furnace or flues, it may be said that any good coal and many poor grades may be used. The following are analyses of coal being used at various plants. In addition to the proximate analysis, the ultimate is also given where available.

The former classification of reverberatory coals into "long-flame" and "short-flame" coals seems to have no meaning in the combustion of coal dust in the long reverberatory furnaces of today, because the length of the flame can be controlled by the damper, coal feeders and burners. Physical characteristics that would make a coal unsuited for grate firing are not objectionable in the new system. Consequently it is possible to use in the form of powdered fuel a much greater variety of coal than it was possible to burn satisfactorily on grates.

The ash analyses for a few of these coals are available and are given here:

COAL USED FOR COAL-DUST FIRING

Proximate Analysis

Coal Number	Moisture	Volatile Matter	Fixed Carbon	Ash	Heating Value B.t.u. per Lb. Dry	Heating Value B.t.u. per Lb. Wet	Ultimate Analysis H_2O	H	C	N	Ash	O	S
1	4.3	34.7	55.4	9.5	13,500	12,850	Not available						1.3
2	7.0	24.5	46.3	22.1	9,910	9,210	7.0	3.8	51.7	0.6	20.3	12.3	4.3
3	6.5	40.9	43.1	9.5	12,490	11,690	6.5	4.3	65.5	0.9	9.7	12.4	0.7
4	10.5	39.2	42.9	7.4	13,080	12.070	Not available						
5	6.6	38.7	47.8	12.0	12.570	11.870	Not available						
6	9.0	35.5	43.4	12.7	11,500	10,500	Not available						
7	13.3	32.9	38.5	15.3	10.853	9,660	Not available						

Coal Number	SiO_2	FeO	Al_2O_3	CaO
2	48.3	14.0	35.1	0.5
3	48.1	8.2	21.1	8.2
4	56.6	5.1	21.6	11.0
5	54.3	7.2	19.5	9.1

One can readily see that the ash of coals Nos. 3, 4 and 5, if agglomerated into an accretion of the composition shown, would make a sticky mass at moderately high temperatures. This is exactly what happens in the hotter part of the reverberatory-furnace flue, but the removal of these sticky masses is only a matter of minor importance. That which falls on the slag bath in the furnace is all the more easily fused into the slag because of this slagging tendency of the ash itself. Small additions of limerock flux rabbled into the scum at the slag-skimming bay a few times a day is sufficient to complete the fusion. One must know the origin of the ash of coal No. 2 to understand its behavior. It is due to three things, at least: A large quantity (about 8%) of "sulphur balls," which are hard, heavy concretions of iron

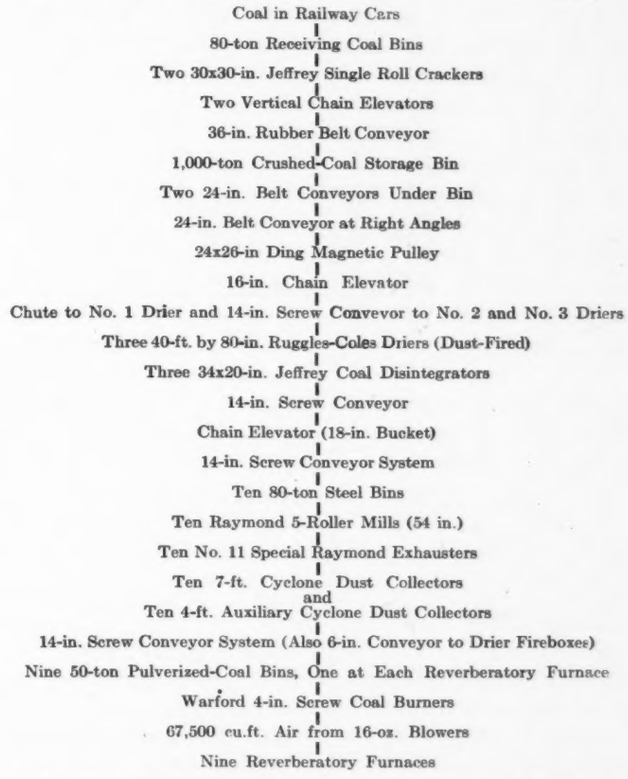

Coal in Railway Cars
80-ton Receiving Coal Bins
Two 30x30-in. Jeffrey Single Roll Crackers
Two Vertical Chain Elevators
36-in. Rubber Belt Conveyor
1,000-ton Crushed-Coal Storage Bin
Two 24-in. Belt Conveyors Under Bin
24-in. Belt Conveyor at Right Angles
24x26-in Ding Magnetic Pulley
16-in. Chain Elevator
Chute to No. 1 Drier and 14-in. Screw Convevor to No. 2 and No. 3 Driers
Three 40-ft. by 80-in. Ruggles-Coles Driers (Dust-Fired)
Three 34x20-in. Jeffrey Coal Disintegrators
14-in. Screw Conveyor
Chain Elevator (18-in. Bucket)
14-in. Screw Conveyor System
Ten 80-ton Steel Bins
Ten Raymond 5-Roller Mills (54 in.)
Ten No. 11 Special Raymond Exhausters
Ten 7-ft. Cyclone Dust Collectors
and
Ten 4-ft. Auxiliary Cyclone Dust Collectors
14-in. Screw Conveyor System (Also 6-in. Conveyor to Drier Fireboxes)
Nine 50-ton Pulverized-Coal Bins, One at Each Reverberatory Furnace
Warford 4-in. Screw Coal Burners
67,500 cu.ft. Air from 16-oz. Blowers
Nine Reverberatory Furnaces

FIG. 1. FLOW SHEET OF COAL-PULVERIZING PLANT

[3] "Coal-Dust Firing for Reverberatory Furnaces," by Charles F. Shelby, "Eng. and Min. Journ.," Mar. 14, 1908.

[4] "Coal-Dust Reverberatory Furnaces of Canadian Copper Co.," by David H. Browne, "Trans. A. I. M. E.," February, 1915.

pyrite (FeS_2); a seam of "bone" interbanded with the coal—the "bone" being carboniferous aluminum silicate which, when free of carbon, is an extremely refractory "kaolin"; and the mineral substance of the plants from which the coal was formed—in this case probably a very siliceous substance. At any rate, sources Nos. 2 and 3 give to the ash a highly refractory portion of low specific gravity, and source No. 1 gives a heavy iron sulphide of low melting point. It is very probable that the latter drops unburned into the furnace bath, because of the neutral or slightly reducing atmosphere in the furnace. The former collects on the slag and in the flue as a light fluffy deposit which has been found not to interfere at all with the calorific efficiency in the furnace.

The foregoing few examples show the difference in ash from coals. In studying the behavior of the ash one must consider its composition and its source, because it is made up of (a) mineral substance of plants from which the coal was formed; (b) mineral substances introduced after formation; (c) mineral matter admixed in mining; (d) mineral matter admixed in transport. All these factors affect the melting point of the ash. E. J. Constant[5] found that coal-ash melting points varied from 1,150° C. to 1,700° C. (2,100° F. to 3,100° F.).

The preparation of coal for dust firing consists of drying it to a satisfactory degree and of pulverizing it to such a fineness that it will all burn while suspended in the atmosphere of the furnace in which it is fired. The dryness and fineness may therefore vary between limits depending on the physical properties of the coal and the design of the furnace.

The coal must be so dry that it will pulverize properly and will not pack or ball up to any extent in the coal-feeding and burning device. The maximum percentage of moisture allowable for meeting these requirements depends on the nature of the coal; some may contain more than others and work better in the apparatus. On the other hand, the coal should not be dried to such a degree that the possibilities of explosions and fires in the coal-preparing buildings are very much increased owing to the effort to make the coal as dry as possible. Injury to life and limb may be far more costly than the slight loss of heat that may be entailed in the feeding of slightly less dry but much safer coal to the furnaces.

Some writers have emphasized this loss of heat as an appreciable quantity, but it is almost insignificant as one will soon learn by investigation: An increase of 1% in the moisture content of the coal dust increases by only one one-thousandth the weight of the gaseous products of combustion. The loss of heat in the gases which leave the boilers (at, say, 700° F.) plus the heat required to evaporate the 1% of moisture in the furnace would, therefore, mean a heat loss of about 11 B.t.u., or 0.1% of the heat in the coal. Even if a plant was using coal which cost $5 per ton and using 1,000 tons per day, the value of the heat lost would be only $5 per day, and it is probable that the additional cost of removing the last moisture in the drier would exceed that expense. The combustion in the furnace might be somewhat delayed owing to the excess moisture and the temperature of combustion slightly lower, but in furnaces that have the length of reverberatory furnaces and in which the temperature of combustion is several hundred degrees above the critical temperature of smelting, the writer believes there is no calorific loss other than the 0.1% previously mentioned. For

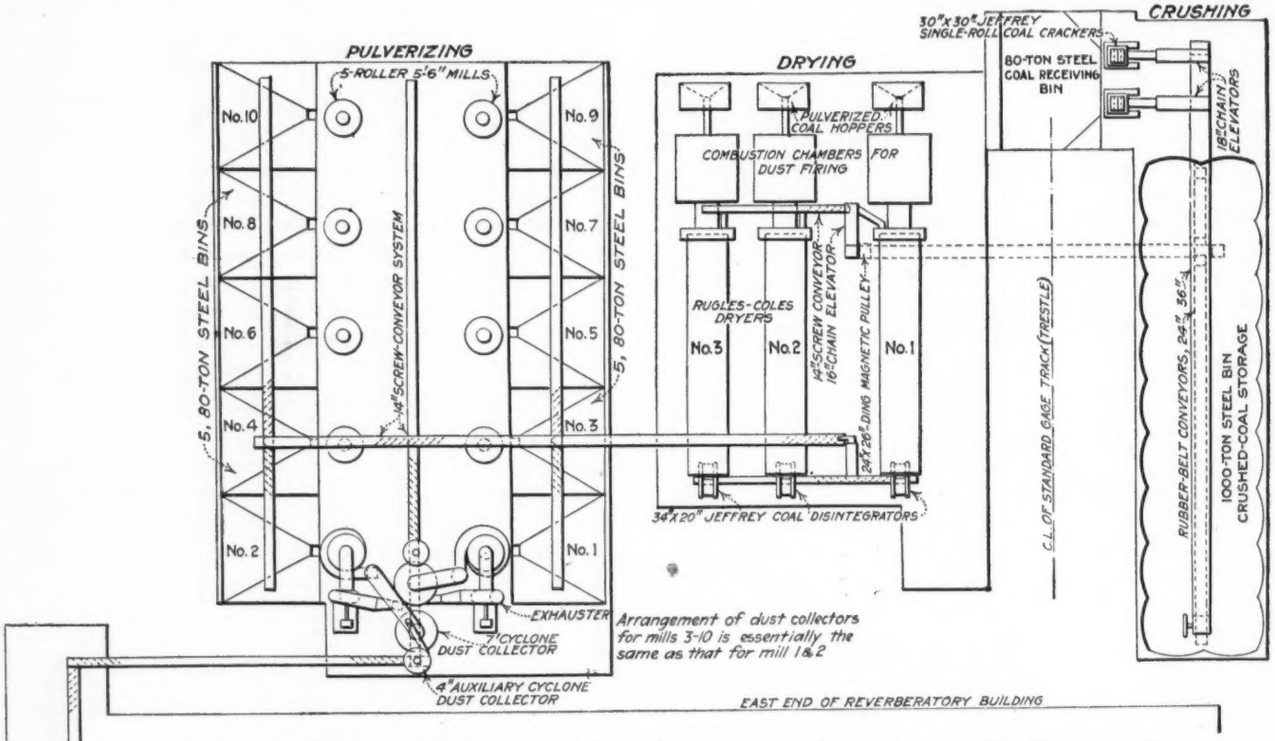


FIG. 2. GENERAL ARRANGEMENT OF ANACONDA COAL-PULVERIZING PLANT

[5] "The Melting Point of Coal Ashes," by E. J. Constant, in "Journ. Gas Lighting," Vol. 124, p. 572.

these reasons it may be said that for reverberatory practice the coal must be dried to such an extent that it may be properly pulverized, conveyed and fed to the furnaces and that it should be dried as much beyond that point as is possible without rendering it unsafe to handle. At Anaconda it has been found that the best percentage of moisture to carry in pulverized coal is 2.5% to 3%.

Coal-Pulverizing Apparatus

Standard coal-pulverizing machinery is usually built to produce coal dust of such fineness that 95% will pass through a 100-mesh sieve and 80% through a 200-mesh sieve. Dust of this size burns entirely satisfactorily in the reverberatory furnace, and slight variations one way or the other have not been observed to make any difference in the fuel ratios obtained.

The apparatus used for preparing coal dust is very much the same at all reverberatory plants. The essential

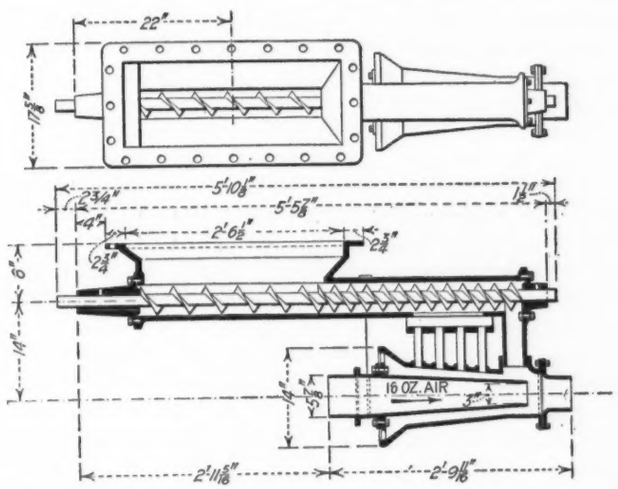


FIG. 3. DETAILS OF WARFORD 4-IN. COAL-DUST FEEDER

parts of the process, drying and pulverizing, are carried out in Ruggles-Coles double-shell revolving driers and in Raymond Bros. roller mills or pulverizers. The dust is collected in centrifugal collectors and conveyed by screws to bins at the furnaces. The correct design and operation of a coal-preparing plant is a subject by itself.

The coal dust is always fed into the furnace by several burners (or feeders or controllers as they are also called), usually four or five. A reverberatory furnace uses from 60 to 100 tons of coal per day and each burner, therefore, feeds as much as 20 tons. The writer knows of only two types of burners in use. Both use a screw conveyor to feed the dust from a pocket in the bottom of the bin to an air-mixing chamber, whence the coal-laden air blast is conveyed into the furnace through a pipe. The Sturtevant burner is used by the Canadian Copper Co. and elsewhere. The Warford burner, shown in Fig. 3, is used by the Anaconda company and was designed by N. L. Warford, superintendent of the Anaconda company's coal plant, to give a more thorough and uniform mixing of air and coal. The projecting portion of the screw is double-threaded to lessen the liability of "flushing," which occurs when a slide of coal in the bin above tends to cause a rush of coal through the burner. A slot is introduced in the screw casing to allow the coal to continuously drop through four pipes into the mixing chamber below. When all the coal dust is discharged at the end of the screw, the amount dropping into the mixing chamber is not the same every instant. The burner pipe used with these burners to feed the coal into the furnace is in the form of an injector. It is simply a 5-in. pipe projecting into an 8-in. pipe. The suction caused by the discharge sucks considerable air into the back end of the 8-in. pipe—in some cases almost as much in volume as the blast air itself.

In neither burner is all the air introduced with the coal. A large portion is sucked in around the burner pipes or through separate ports near the furnace by the furnace draft alone. This air is termed secondary air, as may be, also, the air injected into the 8-in. pipe.

The blast pressure is quite low and varies from 8 to 16 oz. per sq.in. Such air is not costly and may be delivered at the furnace for about 2c. per ton of air.

Coal-Dust-Fired Furnace Operation

All reverberatory furnaces fired with pulverized coal are large modern furnaces, and the installation of the coal-dust method did not necessitate much change in design. The principal dimensions of the furnaces at four large plants are given here:

COAL-DUST FIRED REVERBERATORY DIMENSIONS

Number	Length	Width	Maximum Height of Arch Above Skimplate: Firing End	Flue End
1	112 ft.	19 ft.	6 ft. 8 in.	4 ft. 8 in.
2	143 ft.	25 ft.	7 ft. 6 in.	4 ft. 6 in.
3	112 ft.	19 ft.	.....	.....
4	125 ft.	22 ft.	5 ft. 6 in.	4 ft. 10 in.

Plant No. 1 is at Copper Cliff, Ont.; No. 2 at Anaconda, Mont.; No. 3 at Garfield, Utah; No. 4 at Great Falls, Mont.

The capacity of these furnaces is from 400 to 700 tons of charge per day according to size. A furnace is now under construction at Anaconda, Mont., that will be 153 ft. in length, for treating converter slag. There are eight furnaces of the above dimensions at that plant for ordinary reverberatory smelting.

In three out of four of the plants the method of feeding the charge to the furnace was changed at the same time that the dust firing was adopted. Instead of feeding through holes on or near the center line of the roof, the charge is fed along the side walls and is continuously heaped up on them almost to the roof. The charge is introduced from shallow longitudinal hoppers through pipes about 6 in. in diameter, the pipes being spaced at about 2-ft. intervals. According to this system charge is fed often enough to keep the walls protected all the time, and this means the feeding of small quantities at frequent intervals in contrast to the old practice of feeding large quantities at much longer intervals. One plant of the four mentioned uses the method of introducing the charge through two rows of hoppers 6 ft. 6 in. from the side walls. The side charging is generally thought to be the best because it protects the walls and maintains a more nearly uniform temperature in the furnace.

The operation of charging is carried out by the furnaceman. At each charge hole is a peep-hole through which he can observe the height of the ore lying against the wall. Each charge pipe has its individual sliding shut-off gate operated by a hand lever, so that the charge may be fed in just where it is needed.

The slag is run off the furnace in periodical skims—at intervals of two or three hours at most plants. However, at Anaconda, it is now run off continuously like the overflow of a blast-furnace settler. The scum or unfused floating material that comes down to the "skim-

ming" door is fluxed by additions of small quantities of limestone rabbled in three or four times each shift. In this manner no solids are allowed to overflow with the slag, and prills of matte that would be held in suspension in the viscous excess constituents of the slag settle to the matte bath when that excess material is fused to a fluid slag by union with the added agent. It has been found that copper losses are thus lessened.

Matte is tapped from the dust-fired furnaces in the same manner as from the old grate-fired furnaces. It is not necessary, however, to carry such a large bath of matte as formerly (unless there is considerable excess iron in the slag). The location of the tap-holes has been moved closer to the flue end of the furnace on account of the side charging, which leaves the side walls entirely covered in the other end of the furnace.

The combustion of the coal in the furnaces should be controlled to approach as closely as possible to complete combustion and to discharge the gases at the minimum allowable temperature that will keep the slag in good condition. This temperature is about 2,250° F. (1,230° C.). It is possible to maintain almost perfect combustion; that is, to produce gases containing less than 0.5% of oxygen or carbon monoxide. Samples are repeatedly taken at Anaconda, in which no oxygen or carbon monoxide can be detected by the Orsat gas-analyzing apparatus.

The furnace repairs have been found to be less costly than in the older firing practice. The section of the roof over the hottest part of the flame burns out in less time than formerly, but the tonnage smelted during that time is much greater and hence the repair cost per ton smelted is less.

The economy of dust firing over grate firing is considerable. At Anaconda the same grade of coal that formerly smelted four tons of charge to one ton of coal now smelts seven tons. The furnace capacity is increased, and hence the labor cost is decreased. As already mentioned, the repair cost is also decreased. It is possible to use slack and other cheaper grades of coal. Altogether the saving amounts to so much that it will soon pay for the cost of installation and remodeling. Some plants make a bigger reduction in their reverberatory smelting costs than others, according to their proximity to cheaper fuel. In short the effect of this reduction has been to make the reverberatory furnace the undoubted superior of the blast furnace at many plants and will ultimately bring about the abandonment of the latter type of furnace at those plants.

The writer wishes to acknowledge the free use of the many papers and articles recently published on the use of pulverized coal in reverberatory furnaces. The following papers, other than those referred to in footnotes, have a direct or indirect bearing on the subject of the use of pulverized coal in reverberatory furnaces, and may be consulted for details not given in the foregoing:

"The Use of Pulverized Coal in Metallurgical Furnaces," by James Lord in "Proc. of Engrs. Soc. of West. Penn.," October, 1913.

"Pulverized Coal as a Fuel," Anon. in "Eng. and Min. Journ.," May 16, 1914.

"Coal-Dust Fired Reverberatories at Washoe Reduction Works," by Louis V. Bender in "Trans. A. I. M. E.," February, 1915.

Discussion of Papers on Coal-Dust Fired Reverberatory Furnaces in "Trans. A. I. M. E.," May, 1915.

"Anaconda Coal-Pulverizing Plant," by E. P. Mathewson, in "Eng. and Min. Journ.," July 10, 1915.

"Pulverized Coal for Copper Smelting," by N. L. Warford, in "Min. and Eng. World," Nov. 6, 1915.

"Contribution to Symposium on the Utilization of Fuels in Metallurgy," by E. P. Mathewson, in Inter. Eng. Congress, 1915.

Course of Free Lectures on Military Engineering

A course of seven free lectures on military engineering will be given at the building of the Engineering Societies, 29-33 West Thirty-ninth St., New York City, under the auspices of a committee representative of the four national engineering societies, by Captains Robins, Coiner and Ardery, Corps of Engineers, U. S. A.

This course will be under the direction of Maj.-Gen. Leonard Wood and all engineers interested in preparedness will be welcome.

Through the cordial attitude and coöperation of the United Engineering Society, the auditorium of the Engineering Societies Building has been placed at the disposal of the army officers.

The lectures will begin on Monday, Feb. 14, at 8 p.m., and will continue every Monday thereafter until the completion of the course. Maj.-Gen. Leonard Wood will address one of these meetings. The proposed program is:

Feb. 14—Subject: Organization and duties of engineers in war, and what engineers in civil life will be called upon to do in the defense of the United States. Speaker: Capt. Thomas M. Robins, Corps of Engineers.

Feb. 21—Subject: The service of reconnaissance, including surveying, mapping and sketching, photography and map reproduction. Speaker: Capt. Richard T. Coiner, Corps of Engineers.

Feb. 28—Subject: Field fortifications, sieges and demolitions. Speaker: Capt. Thomas M. Robins, Corps of Engineers.

Mar. 6—Subject: Seacoast defenses and battle-field illuminations. Speaker: Capt. Edward D. Ardery, Corps of Engineers.

Mar. 13—Subject: The construction, maintenance and repair of roads, bridges, and ferries; the selection and preparations of fords. Speaker: Capt. Thomas M. Robins, Corps of Engineers.

Mar. 20—Subject: The selection, laying out and preparation of camps and cantonments; the service of general construction; and the special services, including all public work of an engineering nature which may be required in a territory under military control. Speaker: Capt. Richard T. Coiner, Corps of Engineers.

Mar. 27—Subject: The construction, operation and maintenance of railways under military control and the construction and operation of armored trains. Speaker: Capt. Thomas M. Robins, Corps of Engineers.

The committee in charge of this course is: J. Waldo Smith, chairman; Gano Dunn, chairman, Engineering Foundation; E. L. Corthell, president, Chas. Warren Hunt, secretary, American Society of Civil Engineers; W. L. Saunders, president, Bradley Stoughton, secretary, American Institute of Mining Engineers; D. S. Jacobus, president, Calvin W. Rice, secretary, American Society of Mechanical Engineers; J. J. Carty, president, F. L. Hutchinson, secretary, American Institute of Electrical Engineers; Chas. F. Rand, president, United Engineering Society; Richard S. Buck, J. Parke Channing, Alfred Craven, Thomas Crimmins, George Gibbs, Alexander C. Humphreys, Jacob W. Lieb, William Barclay Parsons, George H. Pegram, Robert Ridgway, Merritt H. Smith, W. H. Wiley; J. S. Langthorn, secretary, 250 West Fifty-fourth St., New York City (Telephone—Circle 1676).

Mine of Chile Exploration Co., Chuquicamata, Chile*

By Pope Yeatman†

SYNOPSIS—As regards tonnage and copper content, the world's greatest copper mine. The ore is principally brochantite; mined on a commercial scale nowhere else in the world. Deposits worked by ancient Indians long before Spanish conquest. Plant, 10,000 tons' capacity, started operation three years after first exploration drilling began. Climatic and labor conditions favorable. Geology is complicated and interesting. Churn drilling aggregated 40,910 ft. to an average depth of 682 ft. Steam-shovel mining used. Water for all purposes brought by pipe line from 40 to 250 mi. distant. Babcock & Wilcox boilers and Swiss steam turbines used in power plant. Long-distance transmission at 110,000 volts. This enterprise of great magnitude is complete success, and plans are being drawn for quadrupling the plant.

The mine of the Chile Exploration Co., situated at Chuquicamata, Chile, is, as regards tonnage and contents of valuable metal, the greatest known copper deposit in the world, and is unique in that its principal copper mineral, brochantite, is mined on a commercial scale in no other locality. The metallurgical treatment chosen—leaching and electrolytic precipitation—is made applicable, and in detail specially designed, for this particular ore, and the plant constructed on a scale to handle the enormous daily tonnages that such a great orebody requires for its proper operation, to make such returns as large business demands, and on a grade of ore that (as is also the case with the large low-grade porphyry deposits in the United States), could only be worked profitably on a large scale.

While American mining engineers have operated in all parts of the world for many years in the employ of foreign corporations, few mining companies owned and incorporated in the United States have operated large properties outside the borders of their own country, with the exception of the neighboring territories of Canada, Mexico and one or two Central American republics. The British, Germans, French, etc., have for many years gone far afield for their investments, but not so with our countrymen, new recruits in the world-wide extension of trade and commerce.

In South America are four large American mining concerns that began operating within the last decade, the most recent one being the Chile Exploration Co., the successful starting of whose plant was inaugurated in May last.

Let us hope that, now the ice has been broken and the trail blazed, other companies from the States will expand and extend their spheres of operations to the territories of our sister republics and that by so doing they may aid in increasing the friendly feeling now growing and draw more closely together socially, commercially and politically, the peoples of the Northern and Southern Hemispheres.

*Paper presented at Second Pan-American Scientific Congress, Washington, D. C., and published by permission.

†Consulting engineer, Chile Exploration Co., 120 Broadway, New York City.

Situation and Extent of Property

The mine of the Chile Exploration Co. is situated at Chuquicamata, province of Antofagasta, Chile, in latitude 22° 17′ south and longitude 68° 55′ west of Greenwich.

The property is situated on a branch, 5.6 mi. long, of the Antofagasta & Bolivia Ry., at a distance of 163 mi. to the northeast of Antofagasta, the port of entry for the district. It lies east of the Pacific Ocean on a bee line about 82 mi. and west of the Bolivian boundary line about 70 mi. The high point of the mine lies at an altitude of 9,890 ft., while the leaching plant is at an altitude of 9,023 ft.

The Antofagasta & Bolivia Ry. is the only line passing through the district, but the company has made surveys and obtained a concession for a much shorter line to Mejillones, one of the best ports on the Chilean coast.

The mining area consists of 242 claims of 644 hectares (1,591 acres); adjoining this are 239 claims of 2,300 hectares (5,683 acres), a portion of which was procured to allow for dumping area on which to deposit capping. The total area consists of 481 claims, or 7,274 acres.

History of Development of Chuquicamata District

The Chuquicamata district is an old one, and the copper deposits are said to have been worked by the Indians even before the coming of the Spaniards, the Indians using the minerals atacamite and brochantite for ornamental purposes rather than for general utility. In the ancient graves are often found ornaments showing the great antiquity of knowledge of the deposit. Later the Spaniards operated the mines in a small way, and in recent years English and Chilean companies have done a considerable amount of mining, both underground and in openpits over a large area. For eight or ten years preceding the beginning of operations by the Chile Exploration Co., very little work had been carried on except in the small vein mines lying outside of the company's property and in which mines the pay ore occurs in shoots rather than continuously. The tonnage obtained, however, from these vein mines has been comparatively small.

Negotiations were entered into and options taken on practically the whole of the main deposit in 1910 and 1911 by Albert C. Burrage, of Boston. In 1912 the Guggenheims became associated with him, and on Apr. 21, 1912, the first drilling was started. Results were so satisfactory that in October of the same year the purchase of the main part of the property was made, and since that time active operations have been conducted in the way of further development of the mine and construction of the plant.

On May 19, 1915, the plant was started on a commercial scale—just over three years from the time drilling commenced. In that time the mine was opened up for steam-shovel mining, a railway for transportation of the ore was built, and a plant of 10,000 tons' daily capacity was de-

signed and built in a desert 5,000 mi. away from the base of supplies.

The government of Chile is a republic, stable and reliable, and no fear is felt regarding the safety of investments made by foreigners in that country. It has been the policy of the authorities to be liberal in their encouragement of mining, and in the past the government has allowed the importation of all kinds of mining machinery either free or at a low tariff.

In the main the government is centralized rather than localized. The courts stand high, and thorough protection is given both to life and to property.

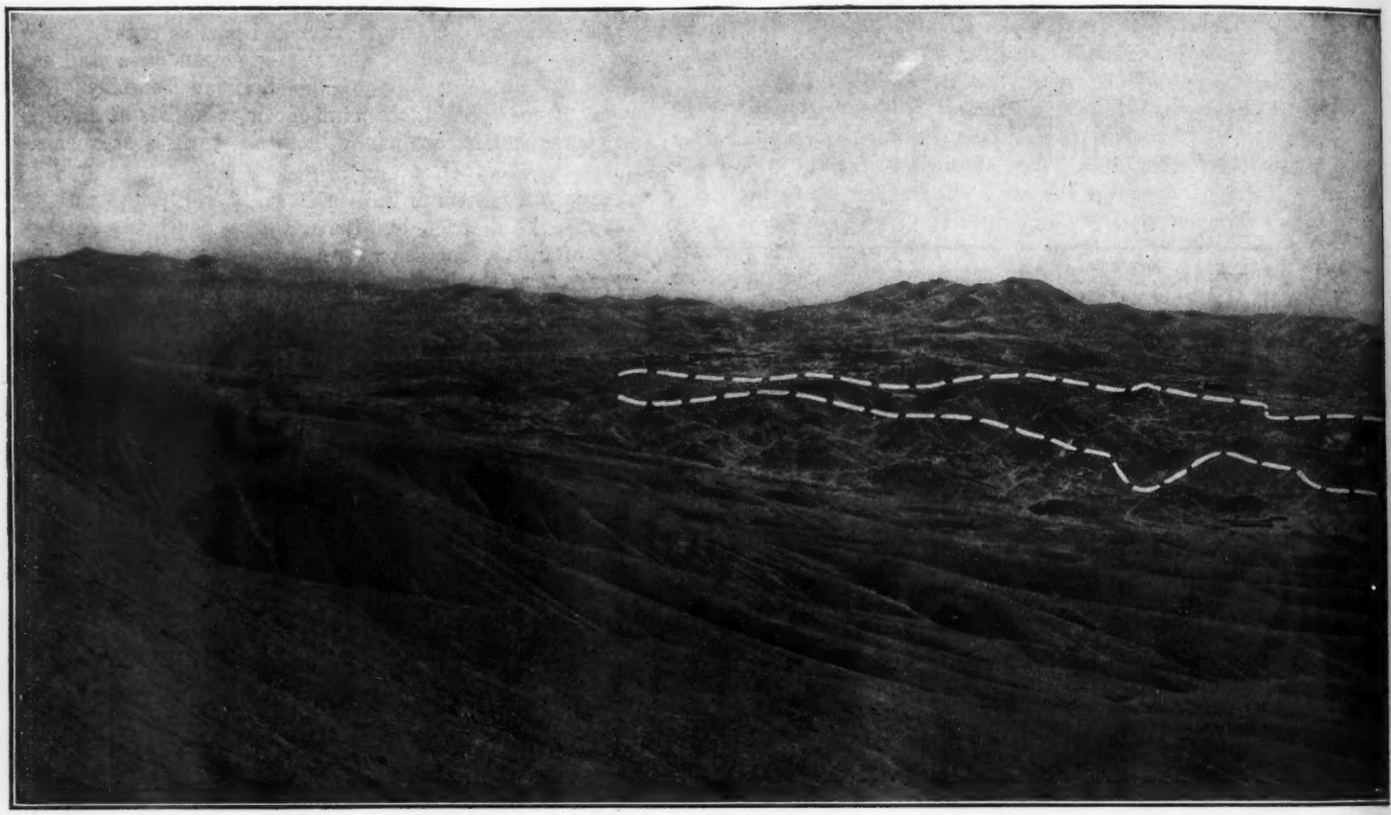
The climate is temperate and extremely healthy, owing to the high altitude. Though within 23° of the equator, the weather is never very hot in summer, and in winter the temperature seldom falls below freezing. The variations between night and day are, however, considerable, as is always the case in dry and high altitudes. The rainfall is almost a negligible quantity. The property lies in the great desert country of northern Chile, and it is possible to carry on work at all seasons of the year without interference or inconvenience. At certain seasons of the year, as is the case in all desert countries, there are high winds, which near roads or villages raise great clouds of dust.

On the open plains themselves, however, ther is almost no dust, for the reason that the fine sand and other eroded material is held together at the surface by crystallized soluble salts, thus forming a sort of crust below which lies more or less unconsolidated fine material. Dews are at times very heavy, and it is largely owing to them in furnishing moisture for dissolving the soluble salts and to capillary attraction that the crusts are formed.

The Chilean workmen are strong and active and, while independent, are quite amenable to authority. They make excellent miners and mechanics and are particularly good on contract work. In northern Chile wages are necessarily higher than in other parts of the republic, for there is no large community in that section to draw from, and it is necessary to recruit from southern or central Chile.

A Study of Geologic Conditions

A study of geologic conditions is extremely interesting, and in particular the economic geology, for the reason that owing to the great aridity of the district in which the mines lie, the commercial minerals of the oxidized portion of the deposit are very different from those in other known deposits of the world, and the amount of easily soluble minerals is unusual.



PANORAMA OF THE PROPERTY OF THE CHILE
The broken line indicates

The conditions under which the primary ores were deposited are similar to those of many other large deposits, and practically the same may be said regarding the secondarily enriched sulphide zone, in which the important copper minerals are covellite and chalcocite; but the oxidized ores bring up new problems, or at least problems which have been neither thoroughly studied nor completely solved.

The Chuquicamata mine lies in high ground between the Coast Range on the west and the great Andes on the east, the crest of the latter forming the boundary between Bolivia and the Argentine on the east and Chile on the

west. The deposit itself occurs in a hill of slight elevation above the valley, sloping gently to the east and more sharply to the west. The outcrop lies with its major axis close to and parallel to the top of the ridge, in a north and south direction. The country rock is a granodiorite extending over a considerable area, which in the ore deposit has been greatly crushed and shows innumerable fractures in all directions, but outside showing little alteration or evidences of such dynamic disturbance. The whole of Chile and, in fact, the west coast of South America lies in an earthquake belt within which dynamic disturbances are still going on, but these, as compared with the period of time during which the great fracturing which resulted in the ore deposit occurred, are small indeed. The fractures outside the main ore deposit are

Using the words of Prof. Charles P. Berkey in a report on rock and ore sent to him and applying them to this particular case, roughly, the history of the primary ore is as follows:

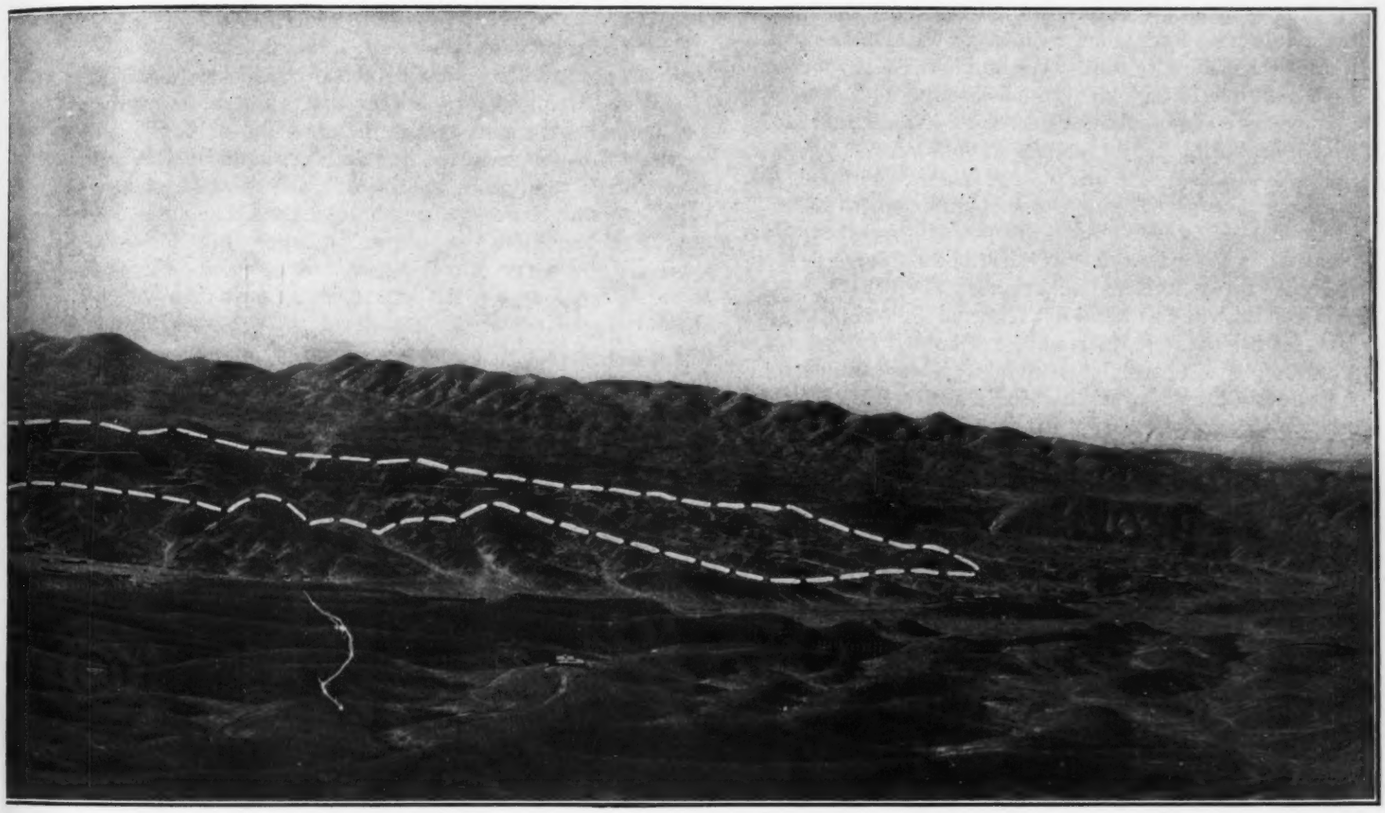
The metallic mineralization is wholly introduced in this rock, and for the most part it dates from a time just subsequent to the latest dynamic disturbance. Previous to that time there was profund chemical attack, perhaps accompanied by or preceded by a dynamic disturbance that is wholly obliterated by the reorganization that accompanied this attack. It is probable that such a disturbance gave the original opportunity for the extensive modification accredited to this rock.

The following are steps in the history:

A. Some medium-grained granitic type of rock.

B. Dynamic disturbance under influence connected with igneous encroachment or igneous activity.

C. Chemical attack carried on by means of circulation either from, or controlled by, igneous influences, producing an aggregate essentially of quartz and sericite.



EXPLORATION CO., AT CHUQUICAMATA, CHILE
the outcrop of the orebody

less numerous, and it is in this latter section that the so-called "vein mines" occur. These veins have a course near the middle of the deposit more or less parallel to the major axis of the orebody, while near the north and south ends the principal veins occur nearly at right angles to that axis.

The ore deposit represents a section of great dynamic disturbance, resulting in intense fracturing of the country rock, thereby making possible the introduction of solutions from below which caused a reorganization of the rock mass and allowed of the introduction later of the primary metallic minerals, these latter filling the fractures and openings and in a small way perhaps replacing some of the constituent minerals of the granodiorite. The solutions not only followed fissures, but penetrated the porous sericitized granodiorite with considerable ease.

D. Subsequent dynamic disturbance, extensively crushing the whole mass.

E. Mineralization with the introduction of metallic minerals and rehealing all of the crevices and replacement of some of the previously existing areas with the introduced substances.

The primary ore represents the originally introduced metallic matter in the ore-bearing ground. In the original fractured rock mass the feldspars have been largely converted into sericite. Quartz occurs as grains in the remnants of the original granite and also in the form of veinlets filling fractures. Silicification of the original rock has also occurred to some extent, silica replacing some of the original constituents. In this primary zone the metallic minerals of the ore deposit were not constituents of the original rock mass, but were the result of mineral-bearing solutions from great depth, which were

deposited simliarly to the manner of mineral deposited in veins, but also to a limited extent as replacements. The metallic minerals are chalcopyrite, bornite and enargite, and except where concentrated into veins of considerable width, have resulted in ore of too low grade to be commercially profitable.

The final concentration of the copper minerals in payable orebodies, in the zone of secondary enrichment, carrying as its valuable mineral constituents chalcocite and covellite, together with remnants of the original chalcopyrite, enargite, bornite and perhaps copper-bearing iron pyrites, has chiefly been effected by descending surface waters of atmospheric origin. The most important action of the descending solutions has been a development of chalcocite by the action of cupric sulphate on primary pyrite and on enargite, and this has been repeated, and as disintegration and erosion removed the upper part, solutions descended and added richness to the remaining portion of the chalcocite zone. The sulphate copper minerals have been due to the oxidation of covellite and chalcocite.

A cross-section shows four more or less distinct zones, which, beginning at the top, are as follows:

First—Leached zone or capping, from which the copper minerals have been removed to such an extent as to result in material of too low grade to be profitably worked. This material is gray in color, much fractured and is iron-stained—particularly on the surface.

Mixed with the soil and detritus and following down a few feet below the surface along cracks and fractures are more or less water-soluble minerals. These soluble minerals are, in the main, salt and sodium nitrate. Along the outcrop most of the barren capping has been eroded, but in the soil there is some salt and nitrate.

This country is the home of the Chilean nitrates, and in it are also found salt and borax deposits, but in the vicinity of Chuquicamata the salts mentioned are not sufficiently concentrated to be workable.

There is a great deal of gypsum present, and this mineral is found not only in the fractures of the rocks, but also cementing the talus from the rock mass.

Second—Oxidized mineral zone, or zone of brochantite. This zone is shown in the outcrop, but also lies under the leached capping in areas along the outcrop and especially on the western side of the latter.

Valuable Minerals Are in Fissures

The material is in the main of a gray color, strongly marked with green, so that a new face in the shovel bench will appear green even from a considerable distance. A face of ore will show altered granite intensely fractured, with the cracks and crevices filled with crystallized brochantite, atacamite, chalcanthite, kroenkite and cuprite, representing copper minerals, also some metallic copper, sulphates of iron, gypsum in considerable quantities, and sulphates of soda, potash and aluminum. In addition certain sections are considerably iron-stained. Most of the cracks are small, but there are some veins of from a couple of inches up to as many feet. Practically speaking, these minerals occur entirely in the cracks and veinlets, though at times there seems to be some dissemination through the rocks; this latter form, however, represents the filling of small openings in the rock connected with cracks. There seems to be little or no replacement.

In the examination of specimens under the microscope, special attention has been given to see what minerals followed one another in time of deposition and to determine what minerals, especially those of copper, were pseudomorphs of others, but so far nothing has been reached. All of the minerals seem to have resulted from crystallization from solutions in open cracks, rather than alteration or replacement of one mineral by another in place.

It had been conjectured that brochantite might have resulted directly from alteration of covellite or chalcocite in place or the direct alteration of chalcanthite, but this sequence we have not been able to trace. Undoubtedly the copper minerals in this upper zone have come from the oxidation of covellite and chalcocite, but just what the changes have been between the secondary sulphides and the remaining sulphates has not been determined.

No Sharp Division Between Sulphides and Oxides

Third—Mixed sulphides and oxidized zone. In our western porphyries, the plane of division between sulphides and oxidized ores is very sharp, but in the mine at Chuquicamata such is not the case, the oxidized and sulphide ores being mixed for quite a depth; and especially in the vein mines, side by side in the same crevice, will be found chalcocite and brochantite, the latter not appearing to replace the former, but apparently filling a space left from the dissolving of the chalcocite. In the same section may also be seen primary sulphide, which shows changes in place to secondary.

Fourth—Secondarily enriched sulphide zone represented by covellite and chalcocite. The secondary sulphides are mainly formed by disintegration and erosion of the original primary ores by oxidation with foundations of sulphate of copper and precipitation as Cu_2S on contact with pyrites and a removal of pyrites and concentration of chalcocite. This continued to be repeated as erosion went on.

Drill holes and shafts show the water level, and it is close to this that the sulphides begin to appear.

Fifth—Primary ore. The secondary sulphides gradually decrease with depth, until nothing remains but unaltered pyrites, chalcopyrite, enargite and bornite. In the upper portion we have straight chalcocite, lower down chalcocite with a primary core, lower still the primary mineral with a sooty coating of chalcocite and finally the unaltered primary sulphide. These changes are typical and are similar to the changes occurring in our low-grade porphyries.

How deep the secondary alteration occurs has not been determined in the main part of the orebody, though in several places on the edges of the deposit the primary ores have been reached. However, in the vein mines represented in the outlying fractures, the change in depth can be well followed from sulphates on the surface to cuprite, metallic copper, chalcocite and finally primaries, in which the vein filling is mainly pyrites with a little chalcopyrite, enargite and bornite. The deeper ore, as the secondaries disappear, becomes too low in grade to be payable, and these sections of the vein mines are being abandoned in consequence.

The country rock is what might be classed as a granodiorite resembling monzonite. Its constituents are quartz, feldspar, mica (biotite) and hornblende, the feldspar being orthoclase, anorthoclase and albite mainly; it is a soda-granite.

The chief minerals of the deposit are as follows:

Metallic copper.....Cu

The Oxide Metallic Minerals:

Chalcanthite.....$CuSO_4.5H_2O$, containing 25.4% copper

Brochantite,
A basic sulphate of copper, $CuSO_4.3Cu(OH)_2$, containing 56.2% copper

Atacamite,
An oxychloride of copper, $Cu_2ClH_3O_3$, containing 59.45% copper

Kroenkite.....$CuSO_4.Na_2SO_4.2H_2O$, containing 18.74% copper

Cuprite.....Cu_2O, containing 88.8% copper

Copiapite.....A basic ferric sulphate, $2Fe_2O_3.5SO_3.18H_2O$

Hematite ..... Fe_2O_3

Limonite ..... $2Fe_2O_3.H_2O$

The Sulphide Metallic Minerals:

Iron pyrites ..... FeS_2

Chalcopyrite.....$CuFeS_2$, containing 34.5% copper

Chalcocite.....Cu_2S, containing 79.8% copper

Covellite.....$Cu_2S.CuS$, containing 67.39% copper

Enargite.....Cu_3AsS_4, containing 48.3% copper

Among the nonmetallic minerals in addition to those making up the granodiorite may be mentioned quartz, gypsum, zircon, tourmaline, alunite, sericite, sodium nitrate and sodium chloride.

The copper minerals commercially important are chalcocite, covellite, brochantite, chalcanthite, kroenkite, atacamite, chalcopyrite, bornite and enargite.

Unlike the low-grade porphyry deposits of the United States, where as a rule but little exploratory work had been done prior to drilling, the outcrop of the Chuquicamata mine had been extensively developed by mining operations in the nature of numerous tunnels, shafts, stopes, etc., but to a shallow depth only. Such, however, was not the case with the orebody as a whole, for the reason that very few of the shafts had been put down to any depth and active mining had been carried below the surface to not over 60 ft. It was necessary therefore for the company to further prospect the deposit by the use of churn drills of the Star and Keystone types.

Development of the Orebody

Since drilling began, not only has ore been developed in depth, but also laterally, both east and west of the boundaries of the outcrop. There have been bored for prospect purposes 60 holes, aggregating 40,910 ft. and of an average depth of 681.8 ft., showing with some of the deeper shafts 361.3 ft. of oxidized ore, 116.3 ft. of mixed oxide and sulphide ore and 58.6 ft. of straight sulphide ore. Besides these many holes have been drilled to determine the thickness of the capping and to be used for blasting waste and capping for the steam shovels. For checking the borings of these holes, numerous winzes have been sunk and many crosscuts driven.

The ore outcrop shows a length of 8,000 ft. and an average width of 554 ft. The drilling, however, has been done over a length of 7,000 ft., an average width of 1,011 ft. and an extreme width of 1,555 ft.

The reason for the comparatively shallow depth of the holes drilled is not because they were stopped on account of passing through the ore, but largely because of accidents, such as the breaking of tools, necessitating the abandonment of the holes before reaching the desired depth.

While in a few drill holes ore of too low grade to be commercially profitable has been reached, in the bottom of all the rest there is still payable ore. A number of holes were stopped even before reaching the sulphides.

Development of the east of the main deposit indicates fairly well the limitations of the orebody in that direction, as shown by the extensive workings in the vein mines. In the drives, crosscuts and shafts the playing out of values can be determined, and it is also possible to see where the general crushing of the country rock due to dynamic disturbances has tapered off, giving more or less solid country rock. Through the latter run a few large fissures rather than numerous small ones. To the west in a line at right angles to the major axis and about the middle of this line, the limits have not yet been reached, though at the present time a width of about 1,800 ft. has been shown.

No. 38, the deepest hole, discloses ore of good grade to a depth of 1,685 ft.; the first 545 ft., however, is leached. The borings from hole No. 38 show the crushed condition of the country rock, and the indications give promise of a further extension of the crushed zone to the west. Somewhere in the valley to the west of hole No. 38 is the limit of the crushed zone and therefore of the orebody. The plane of division, however, between the heavily crushed and less altered country rock has not yet been determined.

It is shown by the drill holes and prospect shafts that during the early period of operations it will be necessary to remove comparatively little capping; as in the section first to be mined, except for one or two small areas, payable ore comes practically to the surface. Drill holes, however, show that for the first 50 or 60 ft. below the outcrop, the ore is of lower grade than that at greater depths.

While very little mining was done below 50 or 60 ft. from the surface, quite a few shafts were sunk to the water level and crosscuts were driven from these shafts in the hope of striking ore concentrated in fissures rather than with the view of finding the values generally distributed throughout a large mass.

Such shafts as the Constancia (361 ft.), Criselia (492 ft.), Tres Marias (285 ft.), Aurelia (335 ft.), San Luis (285 ft.), Balmaceda (500 ft.), Reforma (420 ft.), San José (388 ft.) and Teodora (362 ft.) have allowed us to see in place the character of the material occurring between the surface and water level. It is found that the ore near the surface shows greater disintegration than that at lower elevations, resulting in the easy cleavage along mineral-filled cracks, and it was owing to this condition that former owners were able to mine at a slight profit, which they found impossible by their crude methods in the case of the deeper ore. In mining the upper portions of this low-grade deposit, it was found that by the ordinary methods of extracting ore the mineral in the cracks would drop out. By throwing all the ore mined over screens and discarding the coarse material, a fine product was obtained, containing sufficient mineral to bring the grade of ore shipped up to over 20% copper. Material intermediate between 20-mesh and, say, ½ in. was treated with hand jigs, though with very low extraction. The coarse material thrown over the dump, while still containing some copper, was not physically in condition to allow for profitable extraction of its metal.

Deep Ore Breaks Badly for Concentration

When mining the deeper ore, it was found that instead of the ore breaking along the mineral-filled cracks, it was likely to break across them, and even if breaking along the cracks, the mineral would stick either to one wall or the other. In other words, the copper minerals would not free themselves in such a form as to make it possible to save them to advantage by the old methods. All the deeper shafts have shown richer ore than at present exposed in the old workings, but while the assay in copper

was higher, still the ore was less valuable to the old miners on account of the difficulty in separating the minerals from the waste. The Chilean name given to the deposit was *llampera*, meaning "fines," the mining of which was the object of the former owners.

No other low-grade property has given opportunity at the start for so extensive an examination as has this, for practically the whole of the outcrop has been honeycombed by shafts, adits, opencuts and chambers. There have been numerous deeper shafts, so that with the addition of our drilling, it has been possible in the study of the treatment of the ore to make individual tests on ore from all sections of the property and from various depths below the surface. Testing and study of the sulphide ore was also possible; not only on account of material obtained in the drill holes, but also that taken from veins, which were worked in the ore deposit itself or in the vein mines beyond, and in which the copper minerals were concentrated in narrow widths, making it commercially advantageous for the owners to sink even below the water level.

Drilling operations have been carried on by skilled men from the States under the direction of our engineers, and the sampling and watching of the holes were done under their direction by still other young engineers, so that the greatest care was taken in connection with the accurate testing of the orebody. Duplicate samples were taken for every 5 ft. drilled, one being assayed in Chile and the other at Perth Amboy. Composite samples for every 25 and 50 ft. were taken for testing. Checks and rechecks have been made on the samples, extra holes have been put down close to the original holes and resampling in drifts, shafts and exposed faces has been done.

Development has shown that the separation between oxidized and sulphide ore is not marked by a perfect plane of division; there being a fairly thick zone of mixed oxidized and sulphide. In the case of our low-grade porphyry orebodies in the West, the line of division is very marked and distinct. In addition, the elevation at which the change between oxidized and sulphide ore takes place, varies considerably in different sections of the property. One hole may show sulphide ore, say 400 ft. from the surface, while the second one, starting at the same elevation and not over 400 ft. distant, will show no sulphides for perhaps 300 ft. deeper.

Drilling has been by no means easy, on account of the hardness of the deeper ore, the irregularity as to hardness and the fractured condition of the orebody, which tended to make the holes run crooked and thereby causing breakage of tools. The hardness also made the drilling much slower.

In laying out areas for drilling operations, it was intended to block them off by holes placed at the corners of 200-ft. squares, but this was found unnecessary on account of the even distribution of the metallic contents, so that now the aim is to complete the blocking out of the ground by putting down holes on corners of 400-ft. squares.

It is of interest to note that while the capping generally contains some copper, it is of a very low grade and it is possible to distinguish without trouble between capping and payable ore. Should one merge into the other, it would necessitate either the treatment of considerable unpayable material or the loss of considerable ore that should be treated. The sharp division between the two materials is of very considerable advantage in our mining operations.

Amount and Grade of Ore Reserves

Following is a table of ore reserves as of Apr. 25, 1915:

Oxidized ore	204,384,409 tons	1.952%	copper
Mixed ore	65,787,332 tons	2.983%	copper
Sulphide ore	33,129,047 tons	2.477%	copper
	303,300,788 tons	2.233%	copper
Say		2.000%	copper

It is found in mining low-grade copper ores that the average percentage of copper in ore mined is lower than called for by the assay plans, partly owing to mining lower-grade ore, not at first contemplated, partly to intermixture of low-grade and wall-rock and partly to the tendency of sampling to give higher rather than lower results, so that in estimating the grade of ore it has been deemed wise to reduce the average from 2.233% to 2% copper.

A typical analysis of the oxidized ore is as follows: Moisture, 0.30%; SiO_2, 67.48; CaO, 0.61; CuO, 2.66; Cl, 0.40; HNO_3, 0.05; SO_3, 1.76; S (as sulphide), 0.03; Al_2O_3, 13.39; Fe_2O_3, 1.86; MgO, 0.24; MnO_2, 0.02; Na_2O, 3.46; K_2O, 0.84; loss on ignition, 6.80; total, 99.90%. The ore near the surface is higher in chlorine and nitrates.

Possibilities for Developing Future Ore

While the ore reserves are proved to be tremendous, still the possibility of largely increasing them is not only promising but certain, and confidence in this is based on many reasons:

First, to increase due to greater depth than that taken; the thickness was taken not as shown by the deepest holes, but was an average of all the holes put down, no allowance being made for greater depth by reason of the drills' stopping in good payable ore or neighboring holes showing ore at lower elevations—for instance, in four holes of a block, the first may show a depth of 250 ft., the second 500 ft., the third 750 ft. and the fourth 1,000 ft.; the depth of the block was not taken at 1,000 ft., but as the arithmetical average, or 625 ft.

Second, to increase in lateral extent; this is now being proved by holes to the west of the line of the outcrop, and as stated, we have already shown a width in the middle of approximately 1,800 ft. To a considerable distance to the north and south of this line, the surface conditions are similar, showing the same crushing effects due to great dynamic disturbance. I may say that we have recently put down half a dozen holes in such ground, with a certainty that they would also show up commercial ore, and in every case our prognostications were proved correct. There is a very large area of similar ground yet to be drilled, which shows great promise. In sections of this area are shafts that have gone into ore. The limit to the south is pretty well defined. The crushing shown there is less than where we have drilled, and the thickness of the orebody is not so great. The limit to the north has not been so well defined, but beyond the outcrop in that direction, the crushing effect is not so great as in the main portion of the orebody. In view of the similar and very promising conditions covering the drilling to the west of the orebody and to the possibilities of greater depth than that so far allowed, I feel justified in stating that we will

be able to increase our ore reserves to over 400,000,000 tons.

Owing to the great length, breadth and depth of the ore deposit and the small thickness of capping, it was planned to mine the ore with steam shovels, and this method is now being successfully employed. The topography is such that we can easily attack the orebody and work it with very long faces, thus making it possible to work many shovels and many ore trains without interfering one with the other. The ore breaks well on blasting, but there are many large blocks requiring either blasting or breaking by hammer, to reduce them to sizes easily and cheaply handled. To break these large blocks and further increase the crushing capacity, a new preliminary crushing plant has been designed and will be erected near the main crushing plant. It is to have two jaw crushers 60x84 in. This will allow of loading 60-ton cars with blocks of ore as large as the shovel dippers can take, doing away with the loss of time otherwise required to break these boulders at the face, the breaking of which necessitates the stoppage of work on the steam shovels in order to guard the men from accidents.

The approach from the ore bins at the leaching plant is easy; there is plenty of room for tracks, assembly yards, etc., both at the mine and at the treatment plant. The maximum grade on the railway is 2.60%, there being no adverse between the mine and the ore bins.

Details of Mining Methods Used

The method of mining is as follows:

The shovel bench is laid out, at the end of which is the assembly yard, large enough to hold several 20-car trains; loaded trains of this size are taken from the mine to the ore bins at the leaching plant.

For breaking the ore for the steam shovels, there are two methods employed—one by using churn-drill holes put down roughly on the corners of 25- to 30-ft. squares and drilled to a depth of 1½ m. below the shovel bench floor. These holes are sprung with dynamite in order to cavern them out to allow for a large charge of black powder and are blasted either singly or in batteries. This is a common method in use in our porphyry mines out West. A second plan is the driving of crosscuts and drifts, filling the drift nearest to the open face with powder, and by the explosion of the latter shattering the ore toward the free face.

We have six 95-ton steam shovels of the Bucyrus type capable of handling the waste and ore for the 10,000-ton plant. For delivering cars to and from the shovels and the assembly yards, 45-ton locomotives are used.

Work was started using American shovel runners and locomotive engineers, but it has been possible to train many Spanish and Spanish-American operators for these purposes, and most of the work is now being carried on by their aid. Most of our drilling is also now being done by Chileans. The dynamite used is mainly imported, but black powder is locally made and while of a rather poor quality, is of ample strength to do the work required.

For breaking large blocks small jumper drills are employed, and for squaring up bottom large air drills are used, all with native workmen.

Experiments in leaching the Chuquicamata ores have continued over several years—at first on a very small scale in the assay office itself and then by the treatment of 100-kg. lots, later employing tanks of 2,000-kg. capacity, and later still, tanks of 14,000-kg. capacity and of the same depth as the large tanks erected on the ground. In the fall of 1912 these experiments on the larger scale were made to test, first, the solubility and, second, the precipitation of the copper electrolytically. A great many different samples of many tons each were taken from different parts of the orebody, representing, first, the sampling of the opencuts, deep shafts and crosscuts; second, special lots representing material that might be supposed to be more difficult than the average; third, high-grade and low-grade sections; and fourth, ore that would be more or less contaminated with nitrates or sodium-chloride. Experiments were also made in dechloridizing, in order to find a method to overcome the difficulty due to chlorine gas in the precipitation tanks—chlorine reducing the current efficiency and making ventilation difficult.

Elaborate tests were made in the use of insoluble anodes—the ordinary lead anodes deteriorating rapidly in the solution. Later experiments were made with full-sized anodes and cathodes in order to guard against any possible difficulty when installing apparatus of full size. The determination of a satisfactory acidproof lining for the leaching and solution tanks was also reached after a long-time trial. Testing work was done on a far larger and more elaborate scale than has been the practice heretofore for deciding upon the proper ore treatment.

In addition to the special samples, such as ore from the deepest levels, from either end of the property or from three or four of the deep shafts, leaching tests were also made on 25- and 50-ft. composite samples of all the drill holes put down. All of these tests have in every respect been most carefully and systematically done.

Chuquicamata Ores Particularly Good for Leaching

What makes the process chosen particularly applicable for the Chuquicamata ores is that the ore itself carries more than enough sulphuric acid for the solution of the copper, and that on precipitation of the copper from this solution, acid sufficient for the solution of the next batch and an excess besides is regenerated, which will allow the discarding of solutions if necessary, to avoid fouling of them by continual use. The experiments have proved that very little iron, silica or alumina is taken into the final solution and that it has been possible with the average ore to use the same solution over as many as a hundred times without ill effect.

The method for extracting copper from the Chuquicamata ores has been worked out under the direction of the consulting metallurgist, E. A. Cappelen Smith.

The plant is designed for a capacity of 10,000 tons of average-grade ore per day; crushing the ore to about ½-in. mesh; leaching with sulphuric acid; eliminating the greater part of the chlorine by treatment in drums with metallic copper; precipitating the remaining copper from solution by electrolysis; and melting the cathodes into commercial bars. The treatment of the cuprous chloride formed in the dechloridizing drums, for the recovery of the copper, is either by smelting or dissolving the cuprous chloride with salt and electrolyzing, or by treatment with metallic iron to form cement copper.

In an arid country the question of water is naturally one of great importance, and the obtaining of a sufficient quantity for domestic purposes and for the metallurgical operations is most important. The water supply for

Chuquicamata comes from the high mountains, and the company has concessions covering a supply sufficient for the treatment of from 30,000 to 40,000 tons per day and for domestic purposes in addition. This supply will come from three sources—one requiring a pipe line of 90 km., which will give a supply of sufficient purity for domestic and boiler purposes; another requiring two 12-in. pipe lines 40 mi. long, one of which has already been laid; and the third requiring two pipe lines 54 mi. long. At the present time water for domestic purposes is purchased from the Antofagasta & Bolivian Railway Co. and obtained from a pipe line running from the source in the mountains to Antofagasta, a distance of 250 mi.

The Loa River, rising in the Andes, after being joined by a number of tributaries flows through the desert and nitrate country with a considerable grade to the sea. For a great part of its length it has cut a deep cañon and lies considerably below the table land along its banks. In this watershed the Chile Exploration Co. has obtained concessions for power purposes, amounting in all to 27,000 hp., of which it would be able to utilize about 20,000. To do this, however, it will require five or six installations. While power from the hydro-electric installations would be cheaper per hp.-a. than if obtained from the steam plant at Tocopilla, the cost of installation of the latter would be less and the time of construction far shorter and the labor required much less. At the time of laying out this work it was believed that great difficulty would be experienced in obtaining labor at a reasonable price, so it was thought best to limit the requirements as much as possible. In addition it was felt that the final power needed would be much in excess of that to be obtained from the hydro-electric plant, so it was decided to put in, first, the steam-power plant at Tocopilla and at a later period to make use of the hydro-electro units when more power is called for.

Description of Power-Plant Units

To quote from an article written by Fred Hellmann, the general manager of the Chile Exploration Co.:

"The power for the operations of the plant is derived from the generating station at Tocopilla by means of a transmission line, which delivers at substation A.

"There are installed in Tocopilla sixteen 2,500-kw. boilers of the Babcock & Wilcox type. This type of boiler is fitted with superheaters and economizers and works under a pressure of 12.68 kg. per sq.cm. The steam is given a superheat of 93.5° C., which makes the final temperature of the steam leaving the boilers 287.5° C.

"The boilers are oil-fired; the fuel being residual oil from California, brought to Tocopilla by steamers and delivered into the company's storage tanks there. There are two of these tanks, each having a capacity of 55,000 bbl. The feed water for the boilers is derived from an evaporating plant fed with salt water. The steam from the boilers drives four turbines made by the Escher-Wyss Co., Zurich, Switzerland.

"Attached to each turbine is a 10,000-kw. generator, made by the Siemens-Schuckertwerke. These generators produce a three-phase 50-cycle alternating current at 5,000 volts and 2,000 amperes, which, after passing through the controlling switchboards and safety devices, is transformed in four Siemens-Schuckert 10,000 kv.-a. step-up transformers to a tension of 110,000 volts.

"Under this tension it passes over the transmission line, which consists of three 7-strand cables made up of medium hard-drawn 000 B. & S. gage wire. There are two 3/8-in. Siemens-Martin steel-cable ground wires placed on the towers above the copper leads. The towers are of the lattice, or built-up, type and are made of galvanized steel. They are placed at normal intervals of 220 m., but this distance is exceeded on occasion, where the topography of the country calls for longer spans and where no danger is involved.

"The insulators are of the Locke type, seven in a string, and they have given excellent results under tests for flashover and puncture resistance. The string was tested up to 250,000 volts.

"The length of the transmission line is 140 km., and the current is delivered into substation A at Chuquicamata. It passes through various protective devices and reaches the 10,000-kv.-a. transformers, of which there are again four, where it is stepped down to 5,000 volts. From here it passes to the busbars for distribution.

"About 15,000 kw. pass to the rotary converters, of which there are seven—four of the induction type and three of the synchronous type; 3,000 kw. pass to substation B, where there are three 1,000-kv.-a. transformers which reduce the current to 525 volts. This is the operating voltage of all the motors on the property other than those driving the direct-current generators.

"The conduits from the three 1,000-kv.-a. transformers lead to the 525-volt busbars in the basement of the station, whence distribution is made to the motors of the plant situated within convenient distance. Another portion, about 3,000 kw., is taken directly from the 5,000-volt. busbars to substation C, which is at the east end of the plant and which again distributes to such motors as are in its immediate neighborhood.

"Provision has been made also for taking a portion of the power to the mine, where it will be used for lighting, the driving of hoisting engines, air compressors," etc.

Establishing Necessary Villages

There having been no village at first at the plant site and but a few indifferent buildings at the mine, it has been necessary to provide dwellings for workmen and officials with offices, laboratory, blacksmith, machine, carpenter and electrical shops, warehouses, stores, hospital, boarding houses, etc.

There are two villages—a small one at the mine and the principal one at the plant.

The census of Nov. 16, 1915, shows the following population:

Mine:	Men	Women	Children	Total
Americans and Europeans...	107	34	33	174
Chileans and others.....	550	197	325	1,072
Millsite:				
Americans and Europeans...	411	64	48	523
Chileans and others.....	1,532	599	892	3,023
Total	2,600	894	1,298	4,792

Great attention has been paid to the sanitary policing of the village, a welfare department has been inaugurated and a program laid out for still further ameliorating the condition of the Chilean employees and their families, the European and American skilled workmen and officials. The program includes the very considerable enlargement of the Chilean village, with church, clubs, additional schools, plaza with band stand, messhouses, etc., for the skilled mechanics and for European and American officials a clubhouse and additional quarters for married and single men.

Metallurgical Operations at the Braden Copper Co.*

By R. E. Douglass† and B. T. Colley‡

SYNOPSIS—Mines known and operated for about 100 years. Old methods consisted in hand-sorting the ore and smelting in reverberatories, making 50 to 60% matte, which was shipped to Europe. First mill contained crushers, rolls, jigs, tables and buddles; extraction was low. New mill comprises crushing and coarse concentration followed by regrinding in Marcy and Hardinge mills and concentration by oil flotation. Sulphuric-acid plant, making acid for flotation, consists of Wedge roasting furnaces and chambers of usual type. Choice of blast furnace, rather than reverberatory, for smelting concentrates governed by circumstances wholly apart from metallurgy. Smelting mixture made furnace operation difficult. Converter slags made with only 10% silica. Oil flotation changed charge conditions and made smelting easier.

The mining properties of the Braden Copper Co. have been known for more than a hundred years and have been worked for high-grade ore in a desultory manner for probably all of this time.

The ore during these years was hand-picked at the mine and smelted in small reverberatory furnaces situated in the valleys 40 mi. distant. None of these plants exists today, but inspection of the slag dumps shows that silica and alumina gave lots of trouble. It was apparently the practice to fire the reverberatory until no further fusion was possible and then to scrape off the semifused float containing many unfused siliceous particles but not much metal because the heat had been high enough to liquate out the sulphides. The matte made, judging from the particles contained in the slags, ranged from 50% to 60% copper. This was probably shipped to Europe, as no evidence of further treatment has been found.

In 1904 the possibilities of the then undeveloped property were recognized by William Braden, who interested Barton Sewell in it, resulting in the formation of the first Braden Copper Co., which took over the property. This company developed a sufficiently large amount of ore to warrant greater operations, for which more capital was necessary. The holding company accomplished this and took over the property in 1908.

Situation and Natural Conditions

The mines of the company are in the main Chilean Andes of South America, at an altitude of 8,000 ft. latitude 34 deg. south and longitude 71 deg. 20 min. west. The concentrating, acid and smelting plants are two kilometers west of the mine at Sewell, named for the late president and founder of the company. The property is reached through the Pacific coast port of Valparaiso, thence southward 269 km. by the Chilean State R.R. to Rancagua, and then northeast for 70 km. by the Braden Copper Co.'s private railroad of 30-in. gage.

During eight months of the year operations are seldom hampered by unfavorable weather. In May, June, July and August a considerable snowfall is usual, but the attendant difficulties are only such as are commonly encountered in the mining districts of the northwestern United States.

Ample water is available for present and future needs of the concentrating and smelting plants. Electric power is supplied to all departments by the company's hydro-electric plant of 8,000 kw., in the Cachapoal River valley, about 6,000 ft. lower, through a transmission line 28½ km. long, current being three-phase alternating generated at 2,300 volts and stepped up to 33,000 volts for transmission.

Of the company's employees 95% are Chilean workmen, who are reliable and efficient.

The Concentrating Plants

The original Braden Copper Co. having opened up the mine, built a cart road 36 mi. in length from the valley to the mine, selected a mill site and connected the mine and site by an aërial tram 2 km. long and of 700 tons' capacity. It further connected the two upper mine levels with the main mine aërial-tram station. It installed a small hydro-electric plant of 250 hp. on the mill site, and it built a mill.

The first plant was capable of handling between 200 and 250 tons of ore a day. In it were installed jaw crushers, rolls, Harz jigs, Huntington mills, Overstrom tables and buddles. The percentage of extraction in this plant was not high, but it proved conclusively that the ore was amenable to concentration.

While the present new mill was under construction, this old mill was remodeled for experimental purposes by the present company; Wilfley tables and Frue vanners were added, and the capacity was increased to 400 tons daily. The operation of this plant showed improvement over the former results, but still the percentage of extraction was comparatively low.

At this time the possibilities of flotation by oil, acid and aëration claimed attention, and this mill was used as an experimental plant until the problem was practically solved. From data so obtained, the present practice of milling was built up.

The ore, a shattered andesite carrying approximately 75% of the copper content as chalcopyrite, the balance being mostly bornite and some secondary chalcocite, is brought to the crushing plant from the mine over a 2-km. electric railroad and, after being weighed, is dumped into the coarse-ore bin of 2,300-ton capacity.

From the coarse-ore bins the ore, which is usually sufficiently fine for 25% to pass a 1-in. grizzly, is delivered by steel-belt apron feeders to the 30-in. conveyor belt in two sections serving two gyratories, size No. 7½, preceded by two inclined grizzlies. One 30-in. magnetic pulley at the discharge of the first section of conveyor eliminates pieces of iron and steel received with the ore. The undersize of the grizzlies goes direct to two 72x20-in.

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rolls and to two 6x30-mm. trommels. The 72-in. rolls are run in closed circuit through these two trommels, the undersize going direct as a pulp to the concentrating plant proper. A part of the grizzly undersize is at present being sent to a Marcy mill, the first of several that may be installed to increase the concentrators' grinding capacity.

The discharge of the gyratory crushers, maintained at about a 3-in. maximum diameter, is taken by five 6x30-mm. trommels, the undersize going to the fine-ore bins of 3,000-ton capacity and the oversize to five 48-in. Symons crushers. The Symons-crusher product of approximately a 5/8-in. maximum diameter is dry-screened by twelve 6x30-mm. impact screens, the undersize going direct to the fine-ore bin. The impact oversize is dropped into four 15x36-in. medium rolls, from which the discharge is taken by two 30-in. belt elevators to another set of twelve 6x30-mm. screens, situated at the top of the crushing plant. From there the oversize is continuously gravitated to the medium rolls and to two sets of 15x36-in. and two sets of 16x48-in. finishing rolls running in closed circuit, passing therefrom to the fine-ore bins. All delivery to these bins is made by a 24-in. belt fitted with an automatic weighing machine attached.

As stated previously, that portion of the ore from the 72-in. rolls running in a wet circuit goes direct to the concentrating plant as a pulp, the water-to-solid ratio in all cases being kept as low as possible in order to avoid settling or derangement of the flotation plants from a too diluted pulp. The pulp is concentrated on the upper Wilfley tables, of which there are 48 in three sections of 16 each. All are fitted with a modified riffle that permits the handling of 150 to 200 tons per 24 hr. per table. The concentrates are laundered directly to four pits at the foot of the mill. These are fitted with filter bottoms and used alternately, so that the concentrates are drained to about 10% moisture. The table tails go to the Hardinge mills.

That portion of the ore that was dry coarse-crushed and deposited in the fine-ore bins is sent by three inclined conveyors fitted with individual weighing machines, to three towers feeding that number of sections in the concentrator, each of a nominal 1,500-ton capacity. In each section this dry ore falls from the conveyor on eight 5-mesh impact screens, the undersize going to the upper Wilfley tables, while the oversize goes to one 14x30-in. roll and one 15x36-in. roll in circuit, from which the undersize is also sent to the upper Wilfley tables.

The object of this preliminary coarse concentration is to remove not only clean sulphides, but also the small amount of oxide and metallic copper, often adherent, which, with finer grinding, would be lost in subsequent operations both preceding and during flotation. The feed of these tables is not deslimed, because it is not necessary. Desliming would also add more water to final pulp.

The Marcy mill, recently installed and of which the record for the first 10 days' operation only is at hand, ground an average of 456 tons per 24 hr.; the screen analysis of the feed and discharge being as follows:

SCREEN ANALYSIS

Feed		Discharge	
On 38-mm.	4%		
On 25-mm.	20%		
On 16-mm.	24%		
On 8-mm.	20%		
On 10-mesh	25%	On 10-mesh	4%
Through 10-mesh	7%	On 20-mesh	16%
		On 40-mesh	17%
		On 60-mesh	9%
		On 200-mesh	15%
		Through 200-mesh	39%
	100%		100%

The tails of the upper Wilfleys flow directly to five drag classifiers, feeding four 36-in. and one 48-in. Hardinge mills per section, a total of 15 mills in all. The overflow of these drags is manipulated to eliminate as much —60-mesh from the drag discharge (mill feed) as possible. The following is a typical performance of a 36-in. Hardinge mill equipped with a britannia lining:

Weight of steel in lining, kg	6,900
Weight of cast-iron balls, max. 3½ in., dia., kg	3,500
Consumption of balls per ton ground, kg	0.75
Horsepower, full load	73.5
Tons per 24 hr.	389
Water solid ratio of pulp discharged	0.52 to 1

SCREEN ANALYSIS

	Feed	Discharge
On 4-mm.	5%	....
On 10-mesh	33%	....
On 20-mesh	37%	30%
On 40-mesh	14%	24%
On 60-mesh	4%	10%
On 80-mesh	1%	5%
On 100-mesh	1%	2%
On 150-mesh	1%	4%
On 200-mesh	1%	3%
Through 200-mesh	3%	22%
	100%	100%

On a bench below the upper row of Hardinge mills described is an auxiliary row of nine Hardinge mills, which take the discharge from the upper row through classifiers, as well as the occasional surplus or rushes from the upper Wilfleys that the first row may not be able to handle. The drag classifiers here are manipulated at the overflow in the same way as are the upper mills, in order to eliminate the —60-mesh portion of the pulp as much as possible and to launder it directly to the flotation section. One section of this row and the corresponding section of the upper row are being tried out in closed circuit.

The discharge of the upper and auxiliary Hardinge mills is received by six large double-chain drag classifiers, two in each section, the overflow of which, manipulated to carry as little +60 solids as possible, goes to flotation and the thickened coarse discharge to 42 Wilfley tables, 14 to a section, all equipped with modified riffles.

The tails of these Wilfleys are laundered directly to 18 drag classifiers, feeding the same number of 30-in. Hardinge mills, there being six of each to a section. At present these are lined with silex, flint and local stone blocks; and local and Danish pebbles are used as grinders. Other types of liners and grinders are being experimented with. All these mills are run in closed circuit, with the object of producing the least possible +60-mesh solid in the finished pulp.

The following data are typical of the 30-in. Hardinge finishing mills:

SCREEN ANALYSIS

	Feed	Discharge
On 20-mesh	24.3%	...
On 40-mesh	45.5%	12%
On 60-mesh	15.8%	11.2%
On 80-mesh	5.3%	8.8%
On 100-mesh	3.1%	9.2%
Through 100-mesh	6.0%	...
On 200-mesh	...	10.4%
Through 200-mesh	...	48.4%
	100%	100%

Ground per 24 hr., tons	86.4
Pebble load, kg	5,200
Horsepower	51.9
Water-solid ratio pulp	0.48 to 1

The finished pulp, or overflow from the drags of all sections, is received and sampled in one general distributing box.

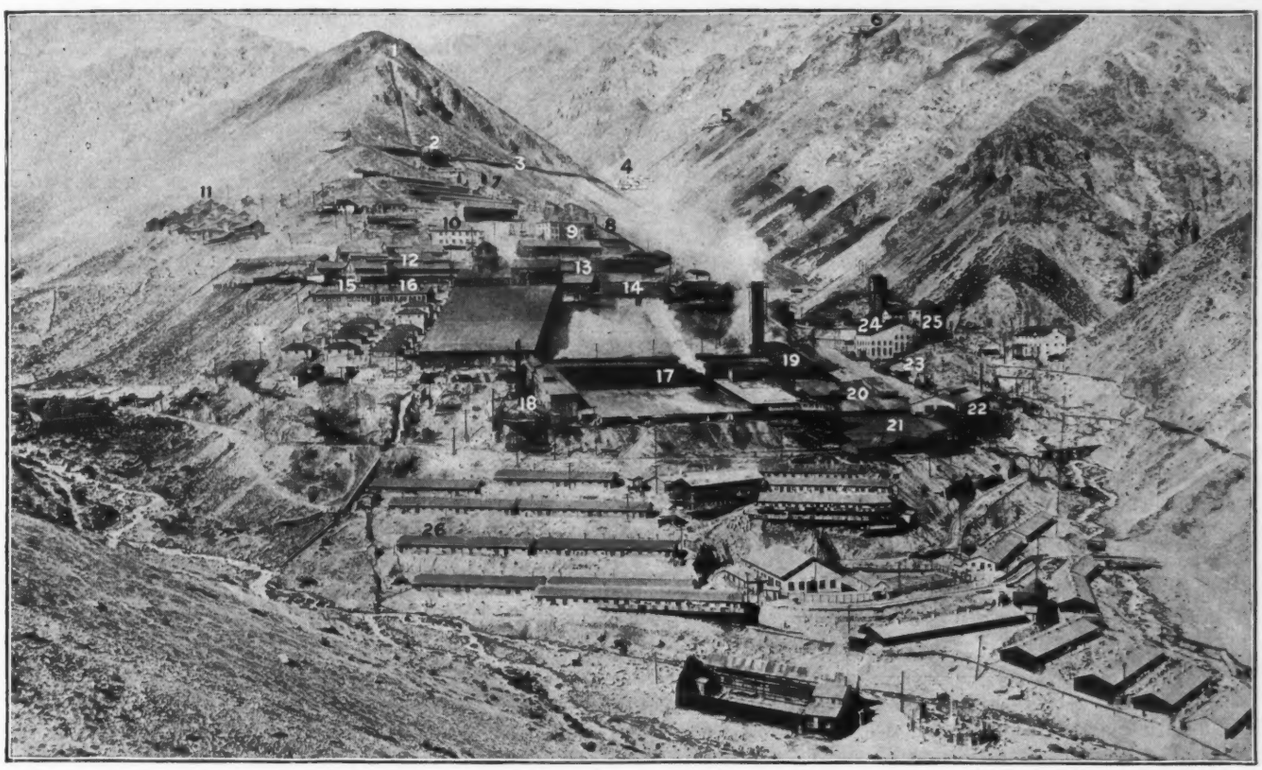
Until recently all this pulp was treated by flotation in six standard valve-type oil-flotation machines, with one more used for the re-treatment of a free-running

froth taken from the tail compartments of the six machines. Another plant was used for the re-treatment of the slime overflow from the flotation concentrates pit. Four of the plants had 9 frothing compartments, two 11 frothing compartments, and two were of 12 frothing compartments. All were originally fitted with 5-in. circulating pipes. Agitator speeds varied from 196 to 214 r.p.m.

Experimental work having demonstrated that increasing the diameter of the circulating pipes to 7 in. and coupling up two plants in tandem would greatly improve extraction and increase capacity, eight plants are being so arranged. The first of these double plants handled

The flotation concentrates are settled in eight pits, four being used alternately. The settled Wilfley and coarser flotation concentrates are loaded directly, by a grab bucket, into side-dump cars for transportation to the acid or smelting plant.

The slime overflow from the flotation concentrate pits, with a water-solid ratio of 10 or 20 to 1 and whose solids, 50 tons per day more or less, are about 98% —200-mesh, is gravitated to a series of Dorr thickening tanks, where it is settled to a density of about 1:1 and then sent to the four Oliver and two Kelly presses. As a rule only four of these presses are in operation at the same time. On account of the exceeding fineness of the material



BRADEN COPPER CO.'S REDUCTION WORKS

The chief features are: 1, penstock and high-pressure water line; 2, coarse-ore bins; 3, electric railroad to mine; 4, 5, 6, adits of Teniente mine; 7, crushing plant; 8, mill; 9, staff house; 10, main office; 11, American townsite; 12, store and warehouse; 13, mechanical shops; 14, foundry; 15, laundry; 16, laboratory; 17, smeltery charge bins; 18, nodulizing cylinders; 19, dust chambers; 20, blast-furnace building; 21, converter plant; 22, electrolytic building; 23, leaching plant; 24, sulphuric-acid plant; 25, roasting plant; 26, native quarters and town. Farther up the hill, near the staff house, a modern hospital has been provided

1,460 tons per 24 hr. on the trial run. Experimental work having shown that no ill effects resulted from returning the free-running froth of the end compartments to the head of the machines for re-treatment instead of to a separate plant, this practice is being continued.

The reagents used are Swedish or American pine-tar oil, fuel oil, sulphuric acid and a small amount of kerosene to thin the fuel oil. A portion of the pine-tar oil is pre-agitated in the lower Hardinge mills, the balance being added at the head of the flotation machine. The acid and fuel oil-kerosene mixture is added at the same point.

To handle the tails from the Minerals Separation standard plants 28 twin (one common partition) air cells have just been installed. The concentrates from the 28 primary air cells will be re-treated in seven additional cells of the same type.

handled, the capacity of the filters is very low. The cake from the filters goes directly to the smeltery.

The mill tailing is flumed downstream, 1½ km., to the storage dam, built in the river valley in such a way that the Coya River is carried under the tailing by a masonry and reinforced-concrete tunnel.

The following is a typical screen analysis of the final tail:

On 40-mesh	5%	On 200-mesh	6%
On 60-mesh	8%	Through 200-mesh	58%
On 80-mesh	8%		
On 100-mesh	7%		100%
On 150-mesh	8%		

The long, turbulent run in the tailing canal, aided by the remaining reagents, raises an appreciable amount of froth which carries some mineral. This is recovered and further flotation induced by a series of automatic frothing boxes placed at the discharge end of the tailing

canal. The concentrate so recovered is sent to the smeltery.

The operating data for the month of October, 1915, are as follows:

Tons milled	121,090
Grade ore, % copper	2.15
Tons concentrates produced	10,708
Grade concentrates, % copper	19.20
Tails, % copper	0.42
Actual extraction, %	80.85

The Sulphuric-Acid Plant

The sulphuric acid used in the oil-flotation process in the concentrating plant is manufactured on the spot. Sulphur is obtained from the Wilfley concentrate having the following analysis:

SiO_2	Al_2O_3	Fe	CaO	S	Cu
13.0	5.7	28.7	1.0	33.0	15.9

The roasting plant consists of one Wedge roasting furnace having seven hearths 21 ft. 6 in. diameter. About 30 tons of concentrate is roasted per 24 hr. The calcines are sent to the smeltery. The acid plant is of the usual chamber type and produces about 20 tons of acid a day, which is more than enough to keep the mill supplied when treating 4,500 tons of ore per day. The acid is blown up to the mill tanks as needed. When all storage tanks are full, the acid plant remains idle until a further supply of acid is necessary.

The First Smelting Plant

The concentrates produced by the small mill, installed shortly after the original Braden Copper Co. took over the mine, were at first shipped in sacks to United States smelteries. The heavy loss in transit, the limited market for concentrates, the distance between mine and smeltery which was too great to allow of very satisfactory control of weights and assays, and the high cost of freight rendered a further concentration at the plant imperative.

With this end in view, smelting experiments were made, including a preparation of the concentrate for blast-furnace smelting by agglomeration, the process used being an adaptation of the pot-roasting process. This was followed by the usual blast-furnace smelting, which was conducted in a small circular furnace 32 in. in diameter and having a 7-ft. ore column. It was provided with cast-iron water jackets. The slag and matte ran into a movable forehearth, from which the matte was tapped while the slag overflowed into a granulating launder. It was soon found that the agglomerating process consumed too much sulphur and oxidized too much iron to allow of a normal grade of matte. The insufficiency of sulphur was supplied by smelting (without roasting) the product of the Harz jigs, which were at that time operating.

This small plant did a lot of work and many hundreds of tons of matte were produced, but owing to the excessive loss of sulphur, the large percentage of fines and the high operating cost, it was plain that the agglomerating process was not practicable. The experiment had, however, suggested the feasibility of briquetting the concentrate without roasting.

At the time the holding company took over the property from the original Braden company, there was developed in the mine only 5% of the present large tonnage, and a reduction plant much smaller than that at present planned was indicated. For the smaller plant there was a sufficiently large power excess to permit of the installation of a leaching plant in which the concentrate would have been roasted in Wedge furnaces, from the gases of which sulphuric acid would have been made, which would have supplied the solvent for the oxidized copper in the roasted concentrates. The copper then in solution would have been precipitated therefrom by electrolysis. The product would have been electrolytic refined copper.

The Second Smelting Plant

With this process in mind as the ultimate reduction plant, it was not the intention to build a permanent smelting plant. There were, however, on the ground several thousand tons of concentrates from which it was desirable to extract and market the copper, and for this reason a 100-ton briquetting plant, a 15-ft. blast furnace and a Peirce-Smith converter were quickly erected and put into operation.

The presence of cheap hydro-electric power and the impossibility of using steam power, added to the fact that the plant is distantly situated from a normal base of supplies and the connecting railroad, then new and far from the stage of smooth running, was loaded down with construction material, caused the adoption of the blast furnace and the rejection of the reverberatory, which is the generally accepted method of smelting concentrates.

The local conditions, together with the circumstances under which this plant had to operate, gave rise to many interesting problems. Limestone was scarce and cost at the plant $12 per ton, while the concentrate was at that time the product of Wilfley tables and Frue vanners analyzing:

SiO_2	Al_2O_3	Fe	CaO	S	Cu
29.0%	15.0	21.5	1.5	18.5	13.0

Being high in silica and alumina, it called for some extraneous flux to form an acceptable slag. The limestone available was calcite, which deflagrated so badly that it would not burn in the ordinary kiln, thus cutting off the possibility of using burnt lime as a binder in the briquette plant until a suitable method of burning it should have been devised.

There was, however, close at hand and cheaply obtainable, a very fat and plastic clay that made an excellent binder, though of course its addition to the concentrate raised the silica-alumina content and called for more extraneous fluxing material.

The experience gained in the operation of the plant showed that the aluminous nature of the concentrate aided by the added clay gave an excellent briquette if thoroughly mixed, and that the metallurgical loss by dust escaping through the stack was negligible if sufficient area was allowed for dust collection by slowing the gases to a speed of from 2 to 3 ft. per sec.

On the other hand, the component parts of the charge were so at variance that great difficulty in furnace operation was encountered. The charge consisted of the following ingredients, mentioned in the order of their quantity and importance:

	SiO_2	Al_2O_3	Fe	CaO	S	Cu
Briquette concentrate	30.0	15.5	21.0	1.0	18.0	15.0
Converter slag	10.0	3.0	57.0	0.5	1.5	4.0
Limestone	3.0	0.5	1.0	50.0		

The concentrate is composed of sulphides easily fusible and only loosely mixed with an andesite gangue that was fused with difficulty. The converter slag is very easily fused. There should be as little lime used as possible.

What happened was that the sulphides would quickly melt and separate themselves from the gangue and run down and out of the furnace; the converter slag would do the same, and there would be left a wall, or hanging, of silica and alumina, fusible only with difficulty, with part of which the lime would form slag and pass down, but the most of which would stay in the furnace unless especially attended to. This condition was aggravated by the short ore column (7-ft.), but the fineness of the charge due to breakage of briquette did not permit of increasing this height. It will be seen readily that the only remedy for such conditions was the use of excessive limestone or excessive coke, or both.

The separation of sulphides from the gangue was most marked. On barring down frozen furnaces, chalcopyrite and bornite would be found plastered on pieces of slag and coke, their composition absolutely unaltered or only partially changed. The chalcopyrite retained its bright-yellow color though it had been thoroughly fused, as was proved by its having adapted itself to, and filled the irregularities of, the piece of slag on which it might be found.

The slags formed were at times high in silica and alumina, shown in the following examples:

SiO_2	Al_2O_3	Fe	CaO	Cu
39.1	14.8	23.5	9.7	0.46
41.1	15.7	21.2	7.4	0.34
38.1	13.4	23.1	12.1	0.38

Owing to the necessity of lowering in all ways possible the silica content of the blast-furnace charge, every effort was made to use the minimum quantity of silica flux in the converter, so that the converter slag might be returned to the furnace with as low a silica content as possible. Most of the United States plants were, at that time, producing converter slag of from 20% to 25% silica content, but it was found possible to make a slag of 10% silica without any apparent harm, though the life of the lining was low, undoubtedly due in great part to lack of experience on the part of the native workmen, who were at that time entirely new to the work of a smeltery.

Effect of Flotation on Smelting

Shortly after the smelting plant began operations, the installation of the oil-flotation process in the mill imposed upon it an entirely new set of conditions. The concentrates produced as shown by this analysis (SiO_2 17.9, Al_2O_3 7.0, Fe 23.0, CaO 0.3, S 30.0, Cu 18.5) greatly improved in grade of copper and of course of sulphur and iron, thus so reducing the silica and alumina that the necessity for limestone as flux disappeared. Also the fine crushing necessary in flotation methods gave a concentrate in which the alumina or colloidal material was so finely divided that it needed no clay as a binder, but which, on the other hand, was so wet that it could not be briquetted and was so fine that it was most difficult to filter or dry it.

These new conditions entirely changed the details of furnace operation. Where formerly the charge was only fairly fine but highly infusible, it was now all fines and excessively wet, but of much lower silica and alumina content and therefore easily fusible. The coke consumption, which under the first set of conditions had been 12%, now rose to 16% per ton of charge. This increase would not be expected in view of the betterment in fusibility of the concentrate. The reason was that each charge of concentrate went into the furnace in one huge blanket of mud that was absolutely impervious to blast penetration. Two such charges dropped on either side of the furnace successfully plugged all blast passages except the longitudinal center line of the furnace. Here the gases were obliged to escape through an extremely reduced aperture at a greatly increased velocity, carrying with them enormous quantities of heat which, under normal smelting conditions, is absorbed by the charge as the gases pass slowly upward.

During this period, when the flotation process was very new and before the arrival of the filter presses, concentrates of moisture content up to 40%, 50% and 60% were smelted in this way. There were times when the concentrate would not stay on the belts and when the coke, which was always placed on the bottom of the charge car, would rise through the charge of concentrate and float on top of it.

The blanketing of the charge and the waste of heat through the narrowed aperture, caused by the water as moisture in the concentrate, were found to cost in increased coke a quantity equal to 50% of the moisture content; that is to say, every ton of water added under these conditions required 1,000 lb. of coke, or 50%, to evaporate it.

The 7-ft. ore column was found to be almost too high for such a dense charge, but on the other hand, any effort to reduce the height allowed such large quantities of water so quickly to reach the tuyeres that chilling of the whole smelting zone was frequent, resulting in frozen spots or total furnace freeze-ups. The average tonnage per day on such a charge in a 300x44-in. furnace was: Concentrate, 135 tons; converter slag, 40; limestone, —; matte, 42; total, 217; coke, 35.

Experiments to Better Condition of Charge

The high consumption of coke made improvement in the physical condition of the charge most desirable, and various experiments were initiated. The percentage of sulphur had so largely increased that it had become possible to sacrifice some of it in sintering. A small down-draft grate was installed. It consisted of low concrete walls supporting cast-iron grates, which were notched to allow of the passage of the gases. A fan was added to draw the gases through these grates. In view of the high percentage of sulphur and the experience with such material in the lead plants, it was feared that quick fusion would occur that later would close the interstitial spaces, preventing the passage of air, and thus stop the operation. No such trouble was encountered. It was found relatively easy to make a good product with concentrate containing over 30% sulphur. Ignition was achieved with a gasoline torch after spreading a small amount of shavings over the bed. The amount of fines through ¼-in. mesh was large if due care was not observed, as much as 25% being common, while an average of from 10% to 15% was normal.

The success of this experiment led to the construction of a plant capable of treating 50 tons a day. Detailed operations were essentially the same as on the experimental plant. The prevention of fines with the maintenance of adequate tonnage was the real problem. The cost proved to be about $1.50 a ton. The sulphur in the product averaged 7%. Though this process gave a good product, its field was limited by the relatively small quantity of sulphur that could be spared from the smelt-

ing operation. Not more than one-sixth of the concentrates could be treated in this way, a quantity too small to sufficiently improve the physical condition of the charge.

About this time it became known that one of the United States plants was treating fines in a nodulizer—a revolving tube slightly inclined, of from 8 to 10 ft. diameter and from 50 to 120 ft. long, lined with brick, fired by oil, gas or pulverized coal at the lower end and fed with concentrates or fines at the upper end.

Investigation of this machine was made in the United States, and it promised so well that experiments were made in a plant close to New York on concentrate that was shipped from Chile. The results of these experiments were so encouraging that an 80-ft. nodulizer 8 ft. in diameter was installed in the smelting plant in Chile, and further and more complete experiments were made.

Kinds of Concentrates Treated

All kinds of concentrates were treated, including the product from Wilfley tables, analyzing SiO_2 13.0, Al_2O_3 5.7, Fe 28.7, S 33.0, Cu 15.9; from the flotation process, analyzing SiO_2 18.0, Al_2O_3 7.6, Fe 21.2, CaO 0.3, S 27.9, Cu 20.3; and from the overflow slimy concentrate, analyzing SiO_2 26.2, Al_2O_3 12.6, Fe 14.7, CaO 0.3, S 19.3, Cu 18.1, filtered by Oliver and Kelly filters.

The moisture content varied from 5% in the Wilfley product to an occasional 50% in the flotation product. The product of the filtration plant averaged over 30%.

The nodulizer handled these various classes of material well, producing an equally good, though slightly different, product from all. Continuous operation was found to be difficult of attainment, because after a few days a heavy ring formed 15 to 20 ft. from the firing end, which gradually increased until it nearly closed. Any efforts to burn or smelt this out gave poor results because, though it reduced the size, it hardened what remained, after which further burning gave no result. To remove this ring it was necessary to shut down the kiln and cut it out by hand labor. Twenty per cent. of the possible operating time was thus lost.

The temperature at the burner end was found to average 950° C., and at the feed end the temperature of escaping gases averaged 400° C. The fuel consumption indicated a rate of 11 gal., or less, of fuel oil per ton of material fed. The indicated tonnage was between 80 and 100 per calendar day.

Owing to the success of this machine, two more were installed. These were 50 ft. long by 8 ft. diameter. The length was reduced because it was thought that, owing to the high sulphur content of the concentrate and its tendency to quick ignition, a shorter time in the machine might give a larger tonnage with a possible decrease in fuel and a greater conservation in sulphur. At that time it was not definitely known how much sulphur could be retained in the product. It was feared that there would not be enough for the smelting operation, but later it was found that there was always enough sulphur remaining and no particular care on this point was necessary.

The 50-ft. kiln proved less efficient than the 80-ft. kiln. It consumed more fuel per ton of material treated because, being shorter, it allowed more heat to escape with the outgoing gases, which averaged 500° C., or 100° more than those leaving the 80-ft. kiln. The tonnage was from 50 to 75, about 33% lower than that of the 80-ft. kiln. Efforts to raise the tonnage to the 80 to 100 figure of the 80-ft. kiln resulted in always having unfused material at the discharge end, proving that the passage through the tube had been too hurried to allow of sufficient heat absorption to produce the incipient fusion, or pastiness, necessary for the formation of nodules.

Long, Large-Diameter Kilns Indicated

The comparative experience of these two kilns indicated the advantage of longer tubes. A kiln 100 ft. long is now in course of erection. It has also appeared, though it has not been definitely proved, that a tube of greater diameter should be advantageous, because in it material would travel a longer distance on the greater circumference and therefore absorb more heat. It would be equivalent to increased length, while at the same time it would allow of the gases passing at a decreased speed. The larger circumference might also lessen the tendency to form the heavy rings of partially fused material which so far have interfered with operations. With this end in view the diameter of the new 100-ft. kiln has been raised to 9 ft.

With a view to doing away with the ring nuisance, there is being added to this tube a drag-chain of the type of the Bergquist chain used at the Gary plant in kilns of this type operating on iron-furnace flue dust. This chain runs continuously through the kiln from the feed to the fire end and returns on the outside, passing through a water-trough cooler before again entering. It is hoped that this arrangement will obviate the necessity of shutting down to dig out the ring.

The smelting of the nodules, the product of the nodulizing furnace, analyzing SiO_2 19.0, Al_2O_3 8.0, Fe 26.6, CaO 0.4, S 17.0, Cu 20.7, proved to be normal blast-furnace practice. The gases passed freely and evenly through the charge, the furnace top was cool, no abnormal hangings formed, the tonnage increased 250% and, most important of all, the fuel consumption fell from 25% to 10% per ton of concentrate, which is 8% per ton of charge.

Features of the Future Plant

While all the details have not been investigated and decided on, nor have the true operating costs been reached, enough has been done to prove that the new nodulizing plant will be installed with mechanical means of cheaply handling the feed and product.

The various items in the blast-furnace charge will be mechanically delivered to bins, from which they will drop directly into measuring boxes and thence to the charge car, thereby doing away with much labor. The charge cars discharge directly to the furnaces. The blast-furnace slag flows into granulating launders and is carried to the river, and the matte is tapped to the converters by means of launders. The converter slag will be granulated and returned mechanically to the blast-furnace charge. The copper will be taken to a casting-machine storage furnace by a crane, from which it may be cast into anodes if a refinery is added, or into the usual bar of blister copper.

It remains to be said that this continuation of processes to form a smelting plant has been due to the conditions peculiar to the Braden problem:

First, because the power is entirely electric and so cheap that a boiler plant such as always exists in a reverberatory plant would be of no service.

Second, because the difficulty in removing the water from the colloidal concentrate indicates that the product will always be wet when delivered to the smelter. Drying would therefore be necessary for a reverberatory plant before the usual roasting.

Therefore physical preparation only would require the use of a machine similar to the nodulizer, with a probable consumption of 4 gal. of fuel oil per ton. There can be no question of the wisdom of lengthening this step to one which, at the expenditure of, say, 6 or 7 gal. more of oil, will do away with the roasting operation and prepare the concentrate for the blast furnace, where the gross fuel consumption is much less than that of the reverberatory, thus giving a minimum total fuel consumption for the nodulizing and blast-furnace processes as compared with drying, roasting and reverberatory-furnace practice. The nodulizer and blast furnace would never replace the standard reverberatory plant except where such extraordinary conditions as those herein quoted exist and where small quantities of copper fines are treated in an established blast-furnace plant and the installation of a reverberatory is not warranted.

Third, the country being steep and difficult of access, the cost of operating the railroad on a 4.5% grade is so high that hauling the minimum amount of fuel is an important object.

Owing to the high temperature (900 to 1,000° C.) employed in the nodulizer and the peculiarly favorable conditions for oxidation, it is decidedly doubtful if this process can be applied to ores, minerals and products that contain silver combined with volatile metals such as lead and zinc, because the losses in fumes would probably be prohibitive.

Metallurgical Operations at the Chile Exploration Co.*

By C. A. Rose†

SYNOPSIS—The metallurgical process used, leaching and electrolytic precipitation, was in detail especially devised for this peculiar type of ore. Plant comprises crushing, leaching, dechloridizing, pumping, precipitating and smelting and melting units. Monster concrete leaching tanks used, discharged by 6-ton clamshell buckets. Dechloridizing plant contains 22 tube-mills 4 ft. diameter by 30 ft. long. Magnetite anodes made in Germany had to be dispensed with on account of the war, and anodes of duriron were successfully substituted. Purity of electrolytic copper produced is higher than product of American refineries.

With the beginning of operations of the 10,000-ton leaching plant of the Chile Exploration Co., Chuquicamata, Chile, in May, 1915, the method of winning copper from its ores by acid-lixiviation and electrodeposition was given its first trial on a really large scale and probably under some of the most favorable conditions that hydrometallurgy of copper will ever have. No other known orebody is so admirably suited to this method of treatment as the oxidized ore at Chuquicamata. The principal mineral in this ore is brochantite, which is a basic sulphate of copper, easily soluble in sulphuric acid. The mineral occurs in the cleavage planes of a gangue that is unattacked by dilute acids, so the method of extracting the copper from the ore by leaching with sulphuric acid suggests itself at once. Also, the electro-deposition of copper from this sulphate solution, thus producing refined copper at one step, presents itself as the most advantageous and feasible method of precipitation.

E. A. Cappelen Smith developed the method of treatment used at Chuquicamata. This plant has been in operation for about six months, and it is gratifying to report that substantially the same results have been obtained in treating the ore on a 10,000-ton scale as on the 15-ton scale in the experiments conducted at Perth Amboy, which Mr. Smith described in a paper read before the American Electro-Chemical Society, Apr. 18, 1914.

The Chuquicamata plant may be divided into the following units: Crushing plant, leaching plant, dechloridizing plant, pumphouse, electrolytic tankhouse, smelting and melting plant. The diagrammatic flow sheet shows the relation of these units to one another.

The crushing plant consists of two No. 10 McCully gyratory crushers, two 48-in. Symons disk crushers and eight 54x20-in. high-speed rolls. The details of this crushing machinery, with belt conveyors, grizzlies, etc., are given in the flow sheet. A heavier burden has been thrown on this crushing plant than was contemplated, since, when the ore is blasted down at the mine, it breaks into larger boulders than was expected. On this account it is necessary to install a primary crushing plant capable of taking these boulders. Construction is now under way for the installation of two 84x60-in. Superior jaw crushers, through which all the ore will pass before it goes to the gyratory crushers now installed. Also, additional grizzlies and screening apparatus are to be installed in the present crushing plant in order to bypass the fine material around each crusher and to return to the roll crushers the oversize from the final product delivered to the leaching plant. The present crushing plant is unable to deliver the full tonnage of 10,000 tons per day, crushed to ½-in. mesh, but it is considered that the modifications outlined will give it this capacity. A considerable percentage of the ore delivered to the leaching plant at present is coarser than ½-in. mesh, and on this account the percentage of extraction from the ore treated has not been so high as was obtained in the experimental plant, where the ore was crushed to the desired fineness.

As is shown in the flow sheet, the leaching plant consists of six leaching tanks, each 150 ft. long by 110 ft.

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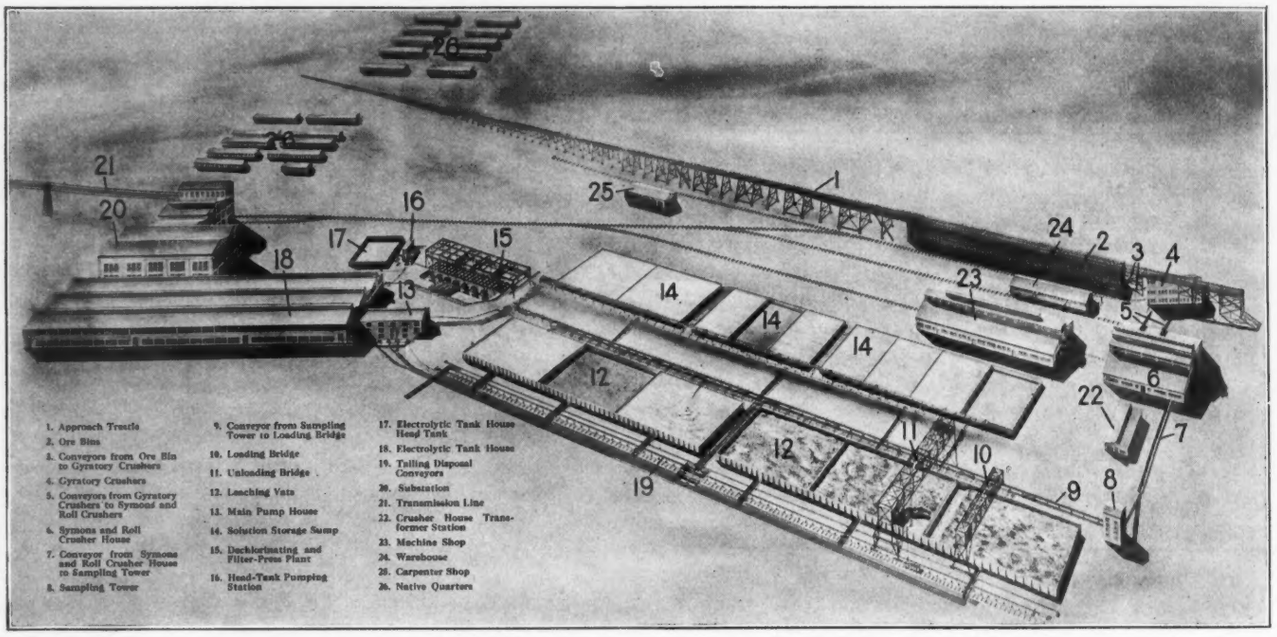
wide by 16 ft. deep, set end to end, and nine solution tanks, which are placed at a somewhat higher elevation. The leaching tanks are spanned by two traveling bridges—one for charging the ore and the other for discharging the leached residue. A 6-ton clamshell grab bucket, suspended from the larger of these bridges, removes the residue from the tanks and delivers it to a belt conveyor, which takes it to the tailings-disposal shuttle conveyor. This belt conveyor is 36 in. wide and about 1,000 ft. long. While it required considerable time to "tune up" the charging and discharging machinery to capacity, the operation of these parts of the plant is now satisfactory.

The leaching tanks and solution tanks are built of reinforced concrete lined with a 1- to 1¼-in. layer of asphalt mastic. On the sides of the tanks, which are vertical, this mastic is held in place by means of expanded-metal lath embedded in the body of the mastic and anchored to the walls of the tank. The mastic consists of one part Trinidad asphalt and four parts sand. The asphalt is melted and mixed with the sand in a Gulich asphalt mixer. When the sand is thoroughly incorporated in the plastic asphalt, the mixture is poured, while still hot, into place between steel forms and the walls of the tank. These steel forms are built up in sections as the lining of the tank is cast. No reinforcement of expanded metal is used in the mastic layer covering the floor of the tank. This mastic lining was tested thoroughly in the experiments conducted at Perth Amboy before the Chile plant was built, and its practicability as an acidproof lining in large tanks has been satisfactorily proved at Chuquicamata.

The leaching tanks have a false bottom constructed of 6x6 timbers laid 10 in. apart on the floor of the tank, with 2x6 planks, 3 in. apart, placed crosswise above these. On this is spread cocoa matting and on the top of the cocoa matting is another layer of 2x6 planks ½ in. apart. When the tank is first charged with ore a 1-ft. layer of coarse material is spread over this false bottom, and when the residue is discharged this layer is allowed to remain, thus forming a perfect sand filter from which all solutions—except the last drains—are withdrawn perfectly clear. Each tank is equipped with eight 6-in. outlet pipes spaced evenly over the bottom of the tank, and these 6-in. pipes all combine into a 15-in. pipe line that leads to the pumphouse. All piping used for conducting acid liquors is of lead-lined iron, joined with standard flanges and rubber gaskets ¾ in. thick. These gaskets take up the expansion and contraction of the pipe caused by the wide daily temperature changes experienced at Chuquicamata. Two sizes only of lead-lined pipe—9 and 15 in. outside diameter—have been used in the construction of this plant.

It was found advisable to conduct leaching in 10,000-ton units from the start. When a tank is filled with ore the first solution is introduced by upward percolation; this is to avoid the washing down into the filter bottom of fine particles which would be caused by liquor descending over the ore if the first solution were applied directly on top of the ore. This first solution is allowed to remain in contact with the ore from 36 to 48 hr., when it is drawn off and replaced with downward percolation by the other solutions in their turn, as shown in the flow sheet.


1. Approach Trestle
2. Ore Bins
3. Conveyors from Ore Bin to Gyratory Crushers
4. Gyratory Crushers
5. Conveyors from Gyratory Crushers to Symons and Roll Crushers
6. Symons and Roll Crusher House
7. Conveyor from Symons and Roll Crusher House to Sampling Tower
8. Sampling Tower
9. Conveyor from Sampling Tower to Loading Bridge
10. Loading Bridge
11. Unloading Bridge
12. Leaching Vats
13. Main Pump House
14. Solution Storage Sump
15. Dechlorinating and Filter-Press Plant
16. Head-Tank Pumping Station
17. Electrolytic Tank House Head Tank
18. Electrolytic Tank House
19. Tailing Disposal Conveyors
20. Substation
21. Transmission Line
22. Crusher House Transformer Station
23. Machine Shop
24. Warehouse
25. Carpenter Shop
26. Native Quarters

10,000-TON LEACHING PLANT OF CHILE EXPLORATION CO.

The following is a sample report sheet showing the solution put on and drawn off in treating one of these tanks of ore.

LEACHING OPERATION SHEET

Charge No. 41 — Date charged, Oct. 9, 1915
Tank No. 5 — Tonnage . . . 8,212 met. tons

Date Oct.	Solutions Put on Grams per Liter Cu.M.	Copper	Acid	Chlorine	Solutions Drawn off Grams per Liter Cu.M.	Copper	Acid	Chlorine
13	3,300	34.8	68.0	1.9				
17	2,560	21.7	69.5	0.7	2,700	47.8	38.0	4.9
18	2,050	25.0	50.4	0.6	2,320	42.1	52.0	3.0
	3,275	36.4	43.6	2.8	3,312	36.3	48.0	2.1
	3,225	30.7	32.8	2.8	3,312	35.4	43.1	2.5
	3,375	21.6	19.6	2.4	3,275	30.9	32.8	2.6
	3,287	7.9	6.4	1.0	3,300	22.1	19.1	2.3
	Water 600 tons				2,800	11.2	7.8	1.1

A portion of the last solution withdrawn from the ore in each cycle is removed for complete deposition of its copper, after which it is discarded. The removal of this solution compensates for the increase in total volume of

ORE HANDLING

Grizzly—On top of ore bin, 8- to 12-in. I's, 40 lb., running longitudinally; across these, 70-lb. rails, spaced 16-ft. centers.

Ore Bin—Length 360 ft., width 35 ft., depth from bottom of grizzly 27 ft. 4 in., capacity 13,000 tons at 90 lb. per cu.ft.

Ore-Bin Feeders—Thirty-two (2 rows of 16), caterpillar type, speed 40 ft. per min., capacity 275 tons per hr. each. Motors—Four; 7½ hp., 470 r.p.m.; feeders in 4 sections, or one motor to 8 feeders.

Conveyors—Ore bin to gyratory crushers. Two; length No. 1, 411 ft., No. 2, 449 ft., width of belt 36 in.; both rise 13 ft. 8½ in., speed 225 ft. per min., capacity 275 tons per hr. Motors—Two; 30 hp., 480 r.p.m.

Motor-Generator—One set magnetic head pulleys, 8 kw., 1,500 r.p.m. Motors, 500 volts; generator (shunt), 220 volts.

Gyratory—Two; type, McCully No. 10; capacity each per hr., 210 tons to 3½ in. and 450 tons to 6½ in.; duty required each, 275 tons per hr.; feed up to 16 in.; product, 3 in. Motors—Two; 120 hp., 480 r.p.m.

Conveyors—Gyratory crushers to Symons disk crushers. Two; length No. 3 186 ft. 4 in., No. 4 203 ft. 4 in. Both—Rise 37 ft. 4 in., speed 150 ft. per min., capacity 275 tons per hr., width of belt 36 in. Motors—Two; 30 hp., 480 r.p.m.

Symons Disk Crushers Style "C" 48 In.—Four; feed 3 in., product 1½ in., capacity each, crushes 100 tons per hr.; main pulley 100 r.p.m., eccentric pulley 250 r.p.m. Fines bypassed to rolls; screens, 1½ in. Motors—Main, 30 hp., 480 r.p.m.; eccentric, 40 hp., 750 r.p.m.

Roll Crushers Garfield 54 Ft. 20 In.—Eight; speed 900 ft. per min., feed 1½ in., product ⅝ in., duty each crusher 46 tons per hr. Balance of 350 tons per hr. screened and bypassed direct to conveyor, screen ¾ in. Motors—Eight; 75 hp., 485 r.p.m.

Cross Conveyor Crusher House—Two; both, length 63 ft. 5 in., rise 0, speed 150 ft. per min., capacity 275 tons per hr. each, width of belt 36 in. Motors—Two; 7½ hp., 500 r.p.m. full-load speed.

Conveyor Crusher House to Sampling Tower No. 7—One; length 352 ft., rise 29 ft. 6 in., speed 300 ft. per min., capacity 550 tons per hr., width of belt 36 in. Motor—One; 75 hp., 485 r.p.m.

Merrick Weightometer

Solution Sumps—Nine; reinforced concrete; two 130x150x12 ft. deep, capacity 6,600 cu.m.; seven 70x150x12 ft. deep, capacity 3,560 cu.m.

Sampling Tower—Three Vezin samplers, 72x48x36 in., cutting 2½% samples, or 407 lb. per day from 10,000 tons per day, driven from motor driving No. 7 conveyor.

Conveyor Alongside Leaching Vats—One; length 1,019 ft., speed 300 ft. per min., rise 11 ft. 17½ in. to tripper on filling belt, capacity 550 tons per hr., width of belt 36 in. Motor—One; 120 hp., 485 r.p.m.

Filling Bridge—Provided with fixed tripper traveling with bridge which engages with belt No. 8 and discharges on the conveyor on bridge. Propelling speed of bridge, 50 ft. per min.; span, 129 ft. 2 in. Propelling motor—20 hp., 960 r.p.m.

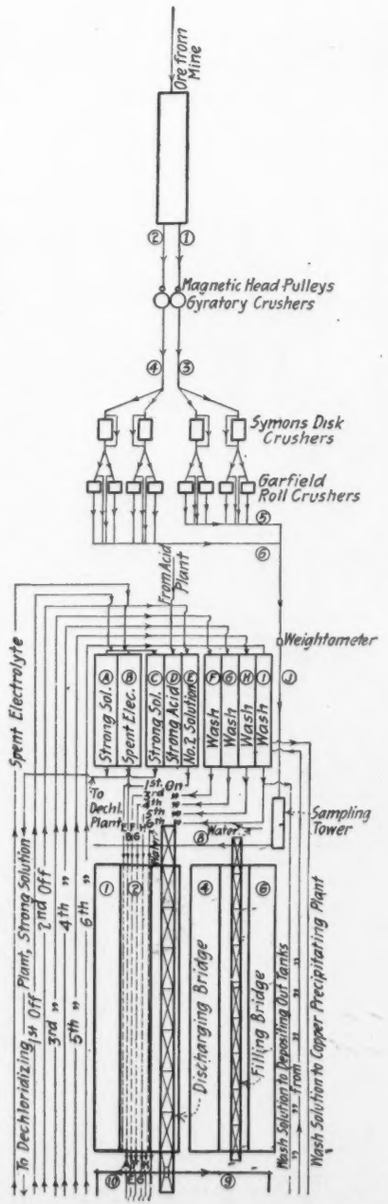
Conveyor on Filling Bridge—One; length 130 ft., speed 300 ft. per min., rise 3 ft. 8 in. to tripper, capacity 550 tons per hr., width of belt 36 in. This conveyor has traveling tripper to provide even distribution of ore in vat. Motor—One; 15 hp., 1,200 r.p.m.

Leaching Vats—Six; reinforced concrete 110x150x16 ft. deep, capacity each 10,000 tons. Bottom provided with filter, consists of 6x6-ft. timbers spaced 10 in. apart; across these 2x6-in. spaced 3 in. apart; over these cocoa matting; and over this 2x6's spaced ½ in. apart; on top always remains 1 ft. ore to protect bottom of vat. For description of flow of solution see general note below

Discharging Bridge—Capacity 550 tons per hr.; capacity grab 6 ton, hoist speed 300 ft. per min. Grab motor, 300 hp., 360 r.p.m. Propelling motor, 70 hp., 750 r.p.m., propelling speed, 50 ft. per min. Trolley motor, 225 hp., 480 r.p.m. Span, 156 ft. 2 in. This bridge discharges through hopper to conveyors 8 and 9. The leached ore is sampled by three Vezin samplers same as in south tower.

Tailings Conveyor—One; reversible alongside leaching vats; length 999 ft. 4 in., speed 300 ft. per min., capacity 550 tons per hr., width of belt 36 in. Motors—Two; 50 hp., 500 r.p.m.

LEACHING



TAILINGS HANDLING

Tailings Conveyors 11 and 11A—Both, length 303 ft., speed 300 ft. per min., rise 16 ft. 2 in., capacity 550 tons per hr. each, width of belt 36 in. Distributing motors—Two; 50 hp., 500 r.p.m.

Tailings Conveyors 13 and 13A Permanent Incline—Both, present length 50 ft. to be extended to 400 ft.; rise, on angle of 20°; speed 300 ft. per min., capacity 550 tons per hr. each; width belt 36 in. Motors—Two; 75 hp., 500 r.p.m.

Tailings Conveyors 12 and 12A Incline Shuttle—Both, length 50 ft., speed 300 ft. per min.; rise, on angle of 20°; capacity 550 tons per hr. each, width of belt 36 in. Motors—Two; 25 hp., 500 r.p.m.

Tailings Conveyors 14 and 14A Horizontal Cross Shuttle—Both, length at present 220 ft., to be extended to 500 ft.; speed 300 ft. per min., capacity 550 tons per hr. each, width of belt 36 in. Motors—Two; 35 hp., 500 r.p.m.; back-gear ratio, 4:1.

Conveyors on End of Shuttle 14 and 14A—Four; length 8 ft.; speed 400 ft. per min.; rise, 0; capacity 550 tons per hr. each; driven from cross-shuttle conveyor.

PUMPING

Head Tanks—Six; reinforced concrete lined with mastic; 2 ft. 10 in. by 14 ft. 4 in. by 5 ft. deep, capacity each 44 cu.m.

9-In. Vertical Centrifugal Acid Pumps—Four; capacity 1,120 gal. per min. against 60-ft. head; 750 r.p.m.; direct connected to two vertical induction motors, motors, 50 hp., 960 r.p.m.

15-In. Vertical Centrifugal Acid Pumps—Two; capacity 4,125 gal. per min. against 60 ft. head; 750 r.p.m.; direct connected to two vertical induction motors, 200 hp., 750 r.p.m.

Green Distributors—Two; 11-way, size of feed 5 in., distributing—3-in. lead pipes.

DECHLORIDIZING

Dechloridizing Drums—Twenty-two; length 30 ft.; 4 ft. 8 in. dia., ½-in. thick steel shell; next to shell 6 in. sheet lead, then 2 in. mastic, then 1⅞ in. earthenware; 8 r.p.m.; flow per drum, 4.7 cu.ft. per min. Motors—Twenty-two; 50 hp., 550 r.p.m.

Settling Tanks—Seven; reinforced concrete lined with mastic; size, 20 ft. dia., 12 ft. high Dorr thickeners, seven; two arms, all wood rake with wooden vertical shaft; 1 r. in 8 m. Motors—Two; 5 hp., 720 r.p.m.

FILTERING

Kelly Filter Presses—Three; type 380 A.B.V.; dia. inlet 4 in., dia. overflow 2 in.; shell 10x4 ft. dia., lead lined; 9 filter frames, 4½-in. centers.

Montejus—Six; shell 8 ft. by 4 ft. 6 in. dia., 1¼-in. cast iron; cone bottom 2 ft. 4 in. deep, lead lined; capacity 3.9 cu.m.

Compressor—One; capacity 250 cu.ft. free air per min. compressed to 150 lb. per sq.in. Motor—One; 50 hp., 750 r.p.m.

Cuprous Chloride Pump—One; Duriron centrifugal, size 1½x1½ in. Motor—One; 5 hp., 720 r.p.m.

Oliver Filter Press—One; width of drum 8 ft. by 11 ft. 6 in. dia.; area 288 sq.ft., ⅛ r.p.m. Motor—One; 10 hp., 600 r.p.m.; back-geared ratio, 5:1.

Vacuum Pump—One; 4x8-in. single-acting Duriron suction pump, driven from 10-hp. motor driving filter press.

Steady Head Receiving Tank—One; 10 ft. dia. by 7 ft. high. Material, 5¼-in. steel plate lined with lead; capacity, 15.5 cu.m.

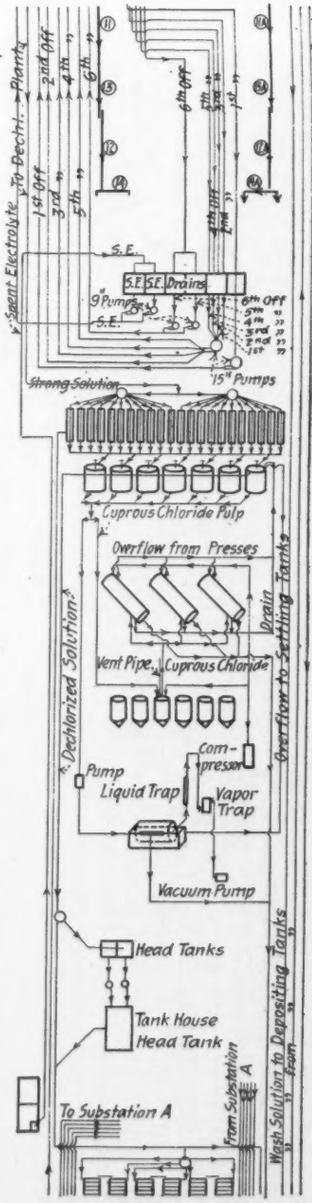
Head Tanks—Two; reinforced concrete lined with mastic; size, 14 ft. 4 in. by 14 ft. 4 in. by 5 ft. deep each inside concrete; capacity each, 29 cu.m.

9-In. Vertical Centrifugal Acid Pumps—Two; capacity, 1,120 gal. per min. against 20-ft. head; 750 r.p.m.; direct connected to two vertical induction motors, 25 hp., 750 r.p.m.

Tank House Head Tank (Storage)—One; reinforced concrete lined with mastic; 90 ft. by 39 ft. 5 in. by 12 ft. deep; capacity, 1,815 cu.m.

Emergency Sumps—Two; reinforced concrete lined with mastic; 64 ft. 8 in. by 32 ft. by 5 ft. deep, divided by cross-wall 8 in. thick running to within 6 in. of top of wall; sump in corner, 7 ft. 8 in. by 7 ft. 6 in. by 4 ft. 6 in. deep.

Green Distributor—Six-way; size of feed, 8½ in.; distributing, 3-in. lead pipe.



FLOW SHEET OF 10,000-TON COPPER-REDUCTION PLANT OF CHILE EXPLORATION CO., CHUQUICAMATA, CHILE

COPPER PRECIPITATING — COPPER-DEPOSITING OUT

Commercial Tanks—Number, 448; reinforced concrete lined with mastic; size, 19 ft. by 3 ft. 6 in. by 4 ft. 10 in. deep (inside dimensions) arranged in 28 sections of 16 tanks cascaded 1 in. tank to tank; depth of solution 4 ft. 6 in. to 4 ft. 7 in.; anodes insoluble (magnetite); size, 4¾ in. by 1⅞ in. by 47 in. to 48 in.; walls, ¼ to ⅜ in.; number per tank, 180 in 36 rows of 5; cathodes, size 3 ft. by 4 ft.—57 per tank; initial distance between electrodes $1^{23}/_{64}$ in. surface to surface; net average volume solution in each tank, 236 cu.ft. (allowing for displacement by electrodes); flow solution per tank, 3.60 cu.ft. per min.; time to renew solution in each tank, 66 min.; copper contents of solution entering 45 grams per liter, average condition; copper contents of solution leaving 15 grams per liter, average condition; current per tank, 13,000 amp. or 15 amp. per sq.ft. of cathode surface or 17.5 amp. per sq.ft. of anode surface. Circuit: amps., 13,300; cross-section of main leads, 26.2 sq.ft.; 508 amps. per sq.ft.

Wash Depositing-Out Tanks—Thirty; reinforced concrete lined with mastic; arranged in 3 sections of 10 tanks cascaded 1 in. tank to tank; flow of solution per tank, 0 to 4 cu.ft. per min. or electrolyze by batches; copper content of solution entering, 8 to 25 grams per liter.

Cathode-Making Tanks—Thirty-two; reinforced concrete arranged in 2 sections of 16 tanks circulation in parallel (not cascaded); anodes (soluble), number per tank 37, size 2 ft. 11 in. by 4 ft. deep by 1¼ in. thick; initial distance between electrodes, 2 in.; net average volume of solution in each tank, 259 cu.ft.; flow of solution per tank 3 to 4 cu.ft. per min.; copper content of solution entering and leaving, 30 to 35 grams per liter; amp. per sq.ft. of cathode surface, 14.8; amp. per sq.ft. of anode surface, 15.

Head Tanks—Two; reinforced concrete lined with mastic; size, 14 ft. 4 in. by 14 ft. 4 in. by 5 ft. deep; capacity each 29 cu.m.

6-In. Vertical Centrifugal Acid Pumps—Two; capacity 225 gal. per min. against 60-ft. head; 1,500 r.p.m.; direct connected to two vertical induction motors, 15 hp., 1,500 r.p.m.

Precipitating Box—Scrap iron precipitating box 10x10x5 ft. deep with cone bottom 5 ft. deep.

Settling Box—Size, 40x10x6 ft. deep, 8-compartment.

Trommels—Three; 6 ft. diam. by 6 ft. 2 in. long; shaft to be Tobin bronze, side plates 1-in. cast copper. Connecting these plates to form trommel are 1-in. hard drawn copper rods spaced 4-in. centers over rods perforated copper sheet. Trommel partially filled with scrap iron, makes 10 r.p.m. Motor driving trommel, 50 hp., 560 r.p.m.

Waste Sump—Waste solution is run into sump filled with scrap iron.

Precipitate Settling Bin—Two; 6 ft. deep, 6 ft. wide, bottom sloping at angle of 40°

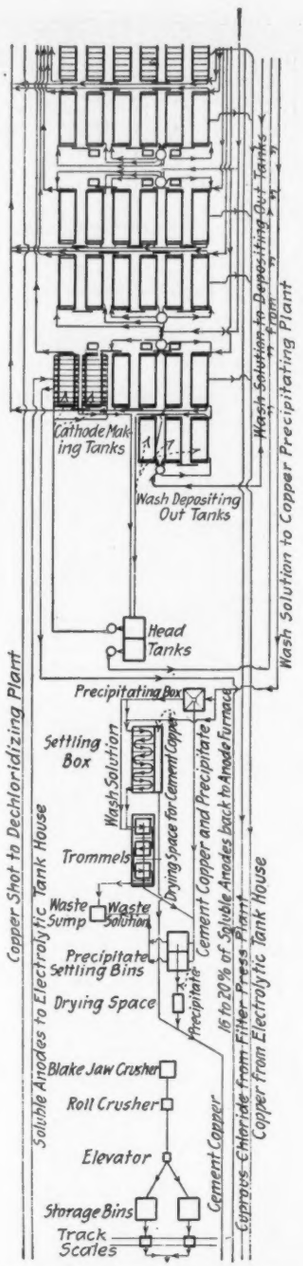
Blake Jaw Crusher—One; size 20x10 in.; capacity 5 tons per hr., crushing limestone and coke to ¾ in.

Roll Crusher—One; size 24x14 in.; capacity 5 tons per hr., crushing limestone and coke from ¾ in. to ⅛ in. Jaw crusher and roll driven by same motor. Motor—25 hp., 1,000 r.p.m.

Chain Bucket Elevator—Length c. to c. 50 ft.; capacity 200 cu.ft. per hr. of crushed limestone, ⅛-in. mesh weighing 135 lb. per cu.ft. Elevator fitted with swivel spout. Motor—2 hp., 930 r.p.m., back-gear ratio, 3.3:1.

Storage Bins—Two; size, 13 ft. 6 in. by 13 ft. 6 in. by 8 ft. 7 in.; 1 limestone, 1 coke; material run direct from bin into cars 2 ft. 6 in. gage, weighed and dumped into bedding bins.

Track Scales—Two; Fairbanks, 10-ton.



COPPER REFINING

Bedding Bins—Three; size, 12 ft. by 8 ft. 8 in. by 3 ft. 9 in., receiving alternate layer of cuprous chloride (direct from dechloridizing plant) and limestone and coke.

Mixers—Two; double-shaft pug mills.

Auger Machines—Two.

Bearing Tables—Two; to cutter.

Cutters—Two; automatic.

Bearing Tables—Two; to cars.

Compressor for Elevator Misc. Tools—Two; capacity 530 cu.ft. free air at 100 lb. per sq.in. Motors—Two; 120 hp., 600 r.p.m.

Pneumatic Elevator—To blast-furnace charging floor; capacity 7½ tons, lift 18 ft., 100 lb. air pressure.

Dust Chamber—Size, 45 ft. by 20 ft. 6 in. by 10 ft. 0 in. deep, with central partition, leaving opening of 10 ft. 5 in. at far end; chamber 9,300 cu.ft.

Blast Furnace—Size, 40x60 in.; area at tuyeres, 16.66 sq.ft.; number of tuyeres, 8; diameter, 4⅞ in.; total area 8 tuyeres, 157.20 sq.ft.; depth crucible below tuyeres, 2 ft. 6 in.; diameter of bustle pipe, 16 in.; blower pressure, 3 lb. per sq.in.; smelting capacity per sq.ft. of tuyere section per 24 hr., 6 tons of charge; total daily smelting capacity, 100 tons of charge; daily capacity to smelt cuprous chloride using pure limestone, 66⅔ tons.

Blowers for Blast Furnace—Two; capacity 6,000 cu.ft. air at 3 lb. per sq.in. Motors—Two; 120 hp., 600 r.p.m.

Compressor for Anode and Wire Bar Furnaces—One; capacity 1,000 cu.ft. air at 15 lb. per sq.in. Motor—One; 120 hp., 600 r.p.m.

Oil Tanks—Four; 9 ft. diameter by 9 ft. deep; capacity each, 4,300 gal.

Shot Pit—Size, 4 ft. 4 in. diameter by 8 ft. 1½ in. high; size shot bucket, 3 ft. 8 in. diameter by 7 ft. 3 in. high with swing door and bottom; weight shot copper, 270 lb. per cu.ft.; capacity bucket, 10 tons; water consumption, 112 tons in 24 hr. approx.

Anode Furnace 100 Tons—Length of hearth, 26 ft. 3 in., width 11 ft. 3 in.; rise hearth center to side wall, 8⅛ in.; spring of roof arch, 12¼ in.; area hearth at metal line, 270 sq.ft., average weight of anodes, 700 lb.; number of anodes per day, 160 to 250; maximum charge per sq.ft. of hearth, 815 lb.; smoke-stack, 86 ft. high by 40½x40½ in. inside.

Anode Casting Machine—Number of molds, 14; number of anodes cast per hr., 100 to 145; size of anodes, 2 ft. 11 in. wide by 4 ft. deep by 1¼ in. thick. Motor—One; 4 hp., 750 r.p.m.

Anode Boshes—Two tanks 4 ft. 8 in. deep by 3 ft. 6 in. wide by 9 ft. 9½ in. long of ¼-in. steel; deep water to overflow 4 ft. 2 in.; sides of tanks fitted with tooth racks to accommodate 19 anodes in each tank spaced 5¾-in. centers; water supply pipe, 2½ in. diameter; anodes handled from wheel to bosh by 2-ton trolley with air hoist span crane 20 ft. 5½ in.

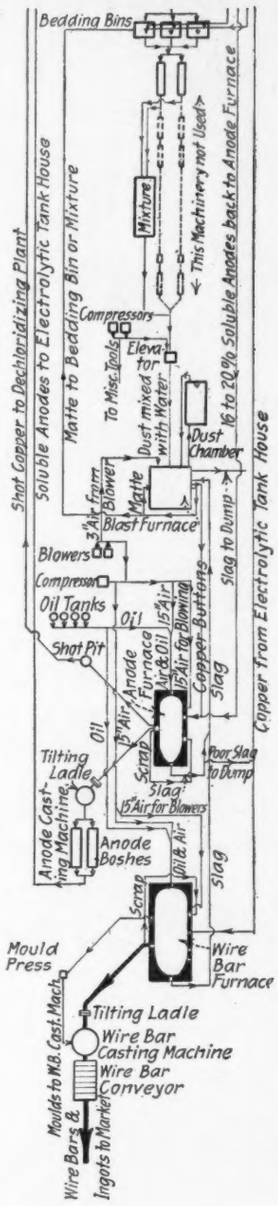
Wire Bar Furnace 165 Tons—Length of hearth 41 ft. 0 in., width 13 ft. 10 in.; rise hearth center to side wall, 1 ft. 1 in.; spring of roof arch, 1 ft. 2 in.; area hearth at metal line, 523 sq.ft.; maximum charge per sq.ft. of hearth, 1,110 lb.; smoke-stack, 85 ft. high by 54x54-in. inside.

Mold Press—One, molds made of copper scrapped molds back of furnace.

Wire-Bar Casting Machine—Number of molds depends on size and style; with 10-ingot mold, number of molds, 13; rate of casting per hr., 30-36 tons. Motor—One; 4 hp., 750 r.p.m.

Wire-Bar Conveyor—Length 21 ft., width 9 ft. 6 in., rise 11 ft. 8½ in.; rate of travel, up to 8 ft. per min.; load of copper on conveyor, up to 4 tons. Motor—One; 2 hp., 1,060 r.p.m.

General Notes—Power for electrolytic tank house, 4 motor-generator sets (induction motors), output 2,500 kw. each set; motor direct-coupled to two generators; output, each generator, 5,300 amp. at 235 volts, speed 495 r.p.m.; motor, 5,000-volt 50-cycle, and 3 motor-generator sets (synchronous motors) duplicates of above except driven by synchronous motor. Output motor, 4,060 hp. with power factor.



FLOW SHEET OF 10,000-TON COPPER-REDUCTION PLANT—Continued

solution due to the addition of more water as a last wash on the ore than is discharged as moisture in the residue and also removes from the system continuously the impurities that are introduced by the ore and that accumulate in the solutions.

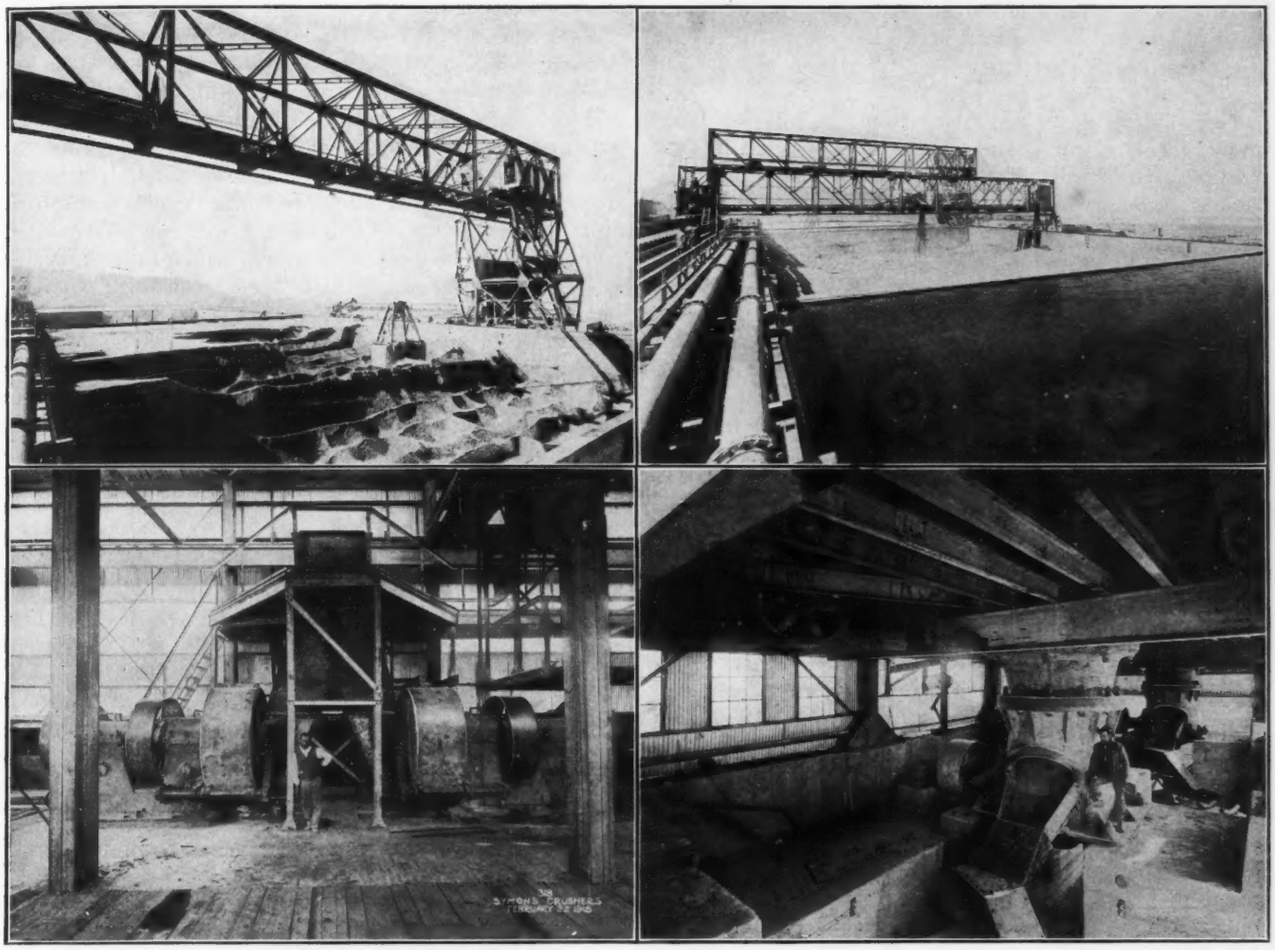
These impurities consist essentially of sulphates of sodium, potassium and magnesium, which are in no way detrimental to the process. They accumulate until the circulating solution contains approximately 150 grams per liter sodium sulphate, 10 grams per liter potassium sulphate and 65 grams per liter magnesium sulphate, after which the discarded solution in each cycle removes the same quantity of these salts from the system as is introduced into the solution by the ore leached. Fortunately iron sulphate does not accumulate in the solutions. The iron content of the circulating solution after the treatment of 45 charges of ore was only 3.4 grams per liter.

The chlorine, which occurs in the ore and is taken into solution with the copper in the leaching operation, is of course an impurity, but provisions were made for the removal of this in the dechloridizing plant, which will be described later. The only other impurity that has made itself manifest in the solution is nitric acid. This comes from the small amount of nitrates found in the surface ores, probably blown there by the winds from the nitrate fields nearby. The accumulation of this nitric acid in the solution is controlled in the same manner as are the alkali salts—that is, by discarding continuously a portion of the last wash solution.

The copper content in this solution removed for complete precipitation is about 6% of the total copper extracted from the ore. The copper precipitated from this solution is either cast into soluble anodes to be used in the electrolytic tanks making starting sheets or is delivered to the dechloridizing drums for the precipitation of cuprous chloride.

The acid lost in discarding this quantity of solution and also in the removal of the acid element chlorine in the dechloridizing plant is approximately equivalent to that gained from the copper sulphate in the ore, which is there in the form of chalcanthite or brochantite, provided the ore is of a grade of not less than 2% copper and does not contain more than 0.2% chlorine. There is an acid plant, however, on the ground in case this loss in acid is more than that gained from the ore.

The leaching of this ore in tanks of dimensions 150x110 ft. with a 12-ft. column of ore has been very satisfactory. That the percolation was uniform throughout the whole charge was demonstrated by the first tankful treated, which yielded 91.4% of its copper content. This demon-



VIEWS AT CHILE COPPER CO.'S PLANT AT CHUQUICAMATA, CHILE

The upper views show the concrete leaching tanks and their equipment. The lower views show a Symons disk and a gyratory crusher in the crushing section

stration was very reassuring and removed all fears of uneven leaching in these big tanks. Although leaching tests were made with the full 12-ft. depth of ore at the experimental plant at Perth Amboy, it was manifestly impossible to forecast from these tests whether percolation would be uniform in a column of ore 12 ft. deep spread out in a tank with an area of over one-third of an acre, so the results from this first charge were awaited with considerable anxiety. The average percentage of extraction from ore treated has not been so high, however, as this first charge; the reason for this was the coarse crushing mentioned.

The dechloridizing plant consists of 22 tube-mills 30 ft. long with an internal diameter of 4 ft. The mills are built of ½-in. steel shells lined with thin lead and with an inside shell of earthenware set in asphalt mastic. They are filled nearly half full of granulated copper and revolved at 8 r.p.m.

The solution flows by gravity from the solution tanks to the dechloridizing plant, where it is divided into 22 streams, each of which flows to a dechloridizing mill. In passing through the mill the chlorine is precipitated as cuprous chloride. The precipitate is held in suspension and carried along by the liquor through the mill and into seven Dorr thickening tanks, where the cuprous chloride pulp is separated from the clear solution. The pulp containing about 50% moisture is delivered from the Dorr thickeners to an Oliver filter. The filter cake from this machine is delivered to the smeltery, where it is mixed with limestone and coke and smelted in a blast furnace; black copper and calcium-chloride slag are produced.

The removal of the chlorine from the solution by these tube-mills has been entirely successful, but minor changes in apparatus, such as launders and filters, have been necessary, and it has been found advantageous to introduce a large percentage of cement copper into the dechloridizing mills with the granulated copper, since by this means their capacity can be materially increased.

Cuprous Chloride to be Treated with Scrap Iron

The treatment of the cuprous-chloride precipitate has been tried at Chuquicamata by smelting, electrolysis and cementation, and results to date indicate that the cementation method will be the most suitable. This is largely on account of the need of supplying cement copper to the dechloridizing mills. The cuprous chloride will be dissolved in brine and passed over scrap iron, where the copper will be precipitated, with a consumption of less than half the usual amount of iron used in cementation plants. The reason for this low consumption of iron is that the copper is present in the cuprous state and the solution contains practically no free acid. Part of the ferrous chloride formed in this reaction will be used in the place of salt to dissolve more cuprous chloride.

The clear solution from the thickening tanks is pumped to an asphalt-lined cement supply tank holding 1,815 cu.m. from which it flows by gravity to the electrolytic tankhouse. The pumping plant is described very fully in the flow sheet, so it will not be discussed further here.

The Chuquicamata electrolytic tankhouse has many unique features; among these are magnetite anodes asphalt-lined cement electrolytic tanks and launders, the large size of the cathodes (3 ft. x 4 ft.) and the cascading of 16 tanks in one solution circuit. Full description of the various parts of the electrolytic tankhouse, with dimensions, is given in the flow sheet. The asphalt-lined cement tanks have proved very satisfactory here as well as in the leaching plant, but at times the solutions have become so warm that the linings in the last tanks of the solution circuits were slightly softened.

The magnetite anodes have proved to be unattacked by the corrosive action of the electrolyte, but in the first months of operation many of these anodes were broken. The operation of an electrolytic tankhouse requires much care and attention. This is particularly true of the tankhouse at Chuquicamata, and with the breaking in of laborers new to this business it was not possible to give the different operations the care desired. On this account many anodes were broken both by rough handling and by unavoidable short-circuits.

After the outbreak of the European War it was impossible to purchase magnetite anodes—since all of these are made in Germany—therefore a substitute was immediately looked for and anodes made of an iron-silicon alloy known as duriron have been largely used as a substitute for magnetite. While this material is not entirely unacted upon when used as an anode in copper sulphate solution, from 15 to 20 times its weight of copper can be deposited before it is entirely corroded away. Duriron anodes have an advantage over magnetite in their mechanical strength, but they have a much higher over-voltage, which is a decided disadvantage. About 15% more electrical energy is required with duriron than with magnetite anodes for the deposition of the same quantity of copper. This extra power goes into heat, and in sections of the tankhouse where duriron anodes are used, the electrolyte is sometimes heated to such an extent that the tank linings are softened. Preparations are now being made to remove the electrolyte from the tankhouse when it is only partly electrolyzed and cool it in a wide cascade launder outside, after which it will be run back into the tankhouse and through another circuit to complete the electrolysis. This is the only material change from the original design found necessary in the electrolytic tankhouse.

The purity of the copper produced at Chuquicamata is somewhat higher than that from American electrolytic refineries; its conductivity is from 100.5 to 101% Matthiessen's standard.

The melting and smelting plant is described very thoroughly in the flow sheet. The only new feature in this plant is the smelting of cuprous chloride. This is done in a blast furnace, and although it has been successful, this process has proved somewhat more difficult than originally contemplated, and the cementation of the cuprous chloride has shown so many advantages over smelting that it is likely that the operation of the blast furnace will be discontinued.

Although the operations of the Chuquicamata plant have not yet been brought up to the full capacity of 10,000 tons per day, this is not on account of any basic defect in the process, but rather due to the usual troubles encountered in starting any new metallurgical plant.

Midvale Absorbs Cambria Steel

The announcement on Feb. 7 that the Midvale Steel and Ordnance Co. had arranged to purchase the Donner-Stotesbury-Replogle holdings in the Cambria Steel Co. brought to a sudden climax the long-pending negotiations for the disposal of the control of the Cambria

company. The Midvale company has agreed to purchase the entire capital stock of the Cambria at $81 per share, the par value of which is $50, though the shares recently sold at $79½. As there are 900,000 shares of Cambria outstanding, the purchase will involve $72,900,000. The Midvale purchase came as a big surprise, following immediately upon the *impasse* reached in the proposed combination of the Cambria, Youngstown and Lackawanna companies.

Cambria assets include the works at Johnstown, Penn., full ownership of the Penn Iron Mining Co. in Michigan, Cambria Inclined Plane Co. and Manufacturers' Water Co. at Johnstown, and half or controlling interest in the Mahoning Ore and Steel Co., Mahoning Steamship Co., Cambria Steamship Co., Johnstown Water Co. and Juniata Limestone Co. It is expected that the capitalization of the Midvale Steel and Ordnance Co. will shortly be doubled.

Hill Publishing Co.

Arthur J. Baldwin has been elected President of the Hill Publishing Co., to succeed the late John A. Hill. Mr. Baldwin is a lawyer and member of the firm of Griggs, Baldwin & Baldwin. For the last 10 years he has devoted

ARTHUR J. BALDWIN

himself almost exclusively to business problems and has been identified with large business enterprises.

At the present time he is treasurer of the Rogers Silver Plate Co.; treasurer of the Borough Development Co., which has a contract with New York City for the removal of ashes from the Borough of Brooklyn; treasurer of the Boston Development and Sanitary Co., which handles all the garbage and ashes for the City of Boston; vice-president of the Automatic Fire Protection Co., and secretary of the Mississippi Wire Glass Co.

Mr. Baldwin was during the last 10 years Mr. Hill's intimate friend and business adviser and brings to the company an intimate knowledge of the latter's policies and plans. He has arranged his business affairs so as to enable him to take active charge of the affairs of this company, which will now be his main interest. The organization of the Hill Publishing Co. will remain intact, and the plans and policies so ably devised by the founder of the business will be carried forward and the standards of practice will be upheld.

Chronology of Mining for January, 1916

Jan. 1—Calumet & Hecla and subsidiary companies began payment to all employees of premium of 10% on their monthly earnings.

Jan. 4—Miami Copper Co. increased its dividend to $1.25 quarterly.

Jan. 6—United States Steel Corporation announced general increase in wages to take effect Feb. 1.

Jan. 10—Party of 18 Americans en route to the mines at Cusihuiriachic, Chihuahua, Mexico, massacred by Villista followers near Santa Ysabel.

Jan. 14—Anaconda company announced increase in wages, effective as of Jan. 1, 1916.

Jan. 17—Striking miners of Clifton-Morenci, Arizona, voted to return to work.—Cyclonic storm wrecked about 500 oil derricks in the Midway and McKittrick oil fields, California.

Jan. 19—Mines of Tennessee Copper Co. closed on account of strike.

Jan. 20—New mill of Yuba Leasing and Development Co., Pioche, Nev., destroyed by fire.

Jan. 22—Decision rendered by Judge Bourquin in Elm Orlu-Butte & Superior case.

Jan. 23—Announcement of increase in wages in Park City, Utah, mines, effective Feb. 1.

Jan. 24—Fire partly destroyed mill of Atolia Mining Co., Atolia, Calif.

Jan. 25—Wage increase decided on by independent operators of the Mesabi Range.

Jan. 27—Terrific wind storm at Coalinga, Calif., destroyed over 500 derricks and rigs, doing total damage of about $1,500,000.

Jan. 31—Pan-American Petroleum and Transport Co. incorporated with capitalization of £150,000,000.

Reagent for Volumetric Coppers

The use of sodium nitroprusside for volumetric copper determination is recommended by G. Duccari (*Ann. Chim. Appl.*, Vol. 2, 1914, p. 287). The solution is titrated with a nitroprusside solution containing 46.866 grams of sodium nitroprusside per liter until a filter paper moistened with ammonium sulphide becomes colored. One cubic centimeter of the sodium nitroprusside solution equals 0.01 gram of copper. Free acid or salts of ferric iron, zinc (except in high concentration), tin, aluminum, lead, manganese, and most of the other heavy metals do not affect the results and the method can be applied directly to solutions of copper which do not contain nickel, cobalt or cadmium.

In the Nomenclature of Antimony Products there are certain peculiarities which are liable to cause confusion to those familiar with copper and lead, according to the Mackay School of Mines "Bulletin." Thus, the name for artificial antimony sulphide is "crude antimony." After this has been reduced to metal, the metal is called "regulus," which, in the case of other metals, is a term synonymous with matte.

Editorials

What Is the Economic Loss by the War?

Sir George Paish, whose name is well known in America, is an eminent economist who is characterized by a practical turn of mind. His optimism is famous. Generally, when we are feeling worried and distressed, Sir George is able to cheer us up by calling our attention to the better side of things and doing it with illuminating words. Lately we have been fearful over the huge mountains of debt that are being piled higher and higher in Europe. We forget that the debits and credits are in the main confined to the same country, the Anglo-French being the only great external loan.

"The war has involved practically no destruction of accumulated wealth," said Sir George Paish, in an interview Dec. 23. "Our loss is mainly in the wealth we fail to create. That is to say, speaking broadly, we are making shells, not building houses; building warships, not making railways. Our main loss arises from the failure to make reproductive expenditure, and this loss is about £400,000,000 per annum.

"It is true," continued Sir George, "that we are selling American securities, but we are buying Russian, French and Italian bonds, and on the balance there has been little reduction in our investment since the beginning of the war. If each one of us were to live economically during the war, we may not need to meet our great war expenses by realizing on our capital, although of course we shall fail to save during the war the usual £400,000,000 yearly of our income that we use for reproductive purposes—building houses, railways, ships, factories, etc.

"As a whole, the world will not in the period of the war save much, and consequently there will be very little expansion in production. On the other hand, the expansion in population will be much smaller than usual, and the economic pressure that would otherwise come from the check to production will thus be minimized.

Temporarily there will be economic pressure of considerable severity at the end of the war. That pressure will be caused mainly by the readjustment of conditions from war to peace. No doubt the wealth of the country will grow as rapidly after the war as it did before the war."

Sir George was manifestly speaking only for Great Britain. In France, Belgium and Poland there has been a large destruction of accumulated wealth, although perhaps only a small fraction of the totals of the several countries. Yet even for Great Britain is not the loss understated? Previous to the war the British annual saving was reckoned by Sir George at about £400,000,000, and it is only that that he now figures as loss. But previous to the war the population that was adding that accumulation to the nation's wealth was paying its own way while doing so. Now a considerable proportion of the working population is not only not saving anything, but also is being supported by the rest of the people. These considerations, moreover, leave out of account the economic loss by the destruction of life and the wounding and maiming of men.

An idea similar to that expressed by Sir George Paish is held by Edmon Théry, of the *Economiste Européen,* who recently remarked that the French government has so far spent in France itself $4,300,000,000 of its war payments and only $900,000,000 abroad. He continued:

"The extraordinary expenses which war imposes on us are not losses in the true sense when they are paid within our own territory. They constitute only a displacement of acquired fortune, for the banknotes paid out by government to settle such expenses spread, through the many channels of public circulation, among all social classes and return, in variable quantity according to individuals, to be transformed in the same government hands into national defense bonds."

Similarly, Horace White, a distinguished American economist wrote recently: "The losses of the warring countries have been chiefly those of able-bodied men. Their producing power has been curtailed thereby. If those men had been at home they would have been earning their own living and something more. They would have been adding to the national wealth. On the other hand, they have been consuming the fruits of the earth without adding thereto, and they have been destroying property in the way of ammunition and other circulating capital. Fixed capital has not been lost or destroyed to any great extent, although it has been put out of use to some extent in Belgium, France, and Germany."

In fact, the alarmists who are appalled by the enormous cost of the war—estimated at 50 billion dollars to the end of 1915 and 2½ to 3 billion per month for its continuance, or figures of about that magnitude—are confusing the cost to the several governments with the cost to the nations. The governments pay out the money in the main to their own people and get it back in the form of taxes, proceeds of bond sales, etc. The great financial operations that are going on are to a large extent processes of redistribution of wealth. This explains the reports of extraordinary prosperity that come from Great Britain along with reports of hard times. This means that persons engaged in certain trades and professions—take the populations of the university towns of Oxford and Cambridge, for example—are being pinched severely, not only by loss of income but also by higher taxation on what remains. On the other hand, persons living in the manufacturing districts are enjoying such prosperity as they never had before, and from masters down to men all are engaging in a riot of personal expenditure for luxuries such as motor cars, jewelry, pianos, fine clothing, etc. In this way occurs a secondary loss from the war—the waste in living within the country itself—and it is for that reason that British statesmen and economists are so urgently preaching carefulness. Such reports come neither from France nor Germany where the characteristic, ever-praiseworthy frugality of those nations is being exhibited in an enhanced degree.

Barnes-King Development Co.

In 1907 we said some severe things about the promotion of the Barnes-King mine, a gold mine at Kendall, in Fergus County, Montana. Under the headings of "The Barnes-King Fiasco" and the "Barnes-King Affair" numerous references to this matter will be found in the *Journal,* Vol. 84, 1907. There was nothing said that was not fully deserved. But Barnes-King is one of the exceptional wildcats that has come back. How it came back was told by our Butte correspondent in the *Journal* of Jan. 22, 1916, but this was not the whole story.

Among the people who were stuck in the original Barnes-King promotion were many mining men of Butte, including several connected with the Anaconda company. They took charge of the Barnes-King company and set about rehabilitating it. About $250,000 remained in the treasury. With this they undertook to acquire new property. They bought the North Moccasin mine, paying $150,000 for it, enlarged and operated the mill on the old Barnes-King mine adjoining, paid $100,000 for the Piegan-Gloster mine, built and operated a 150-ton cyanide mill for it, paid $60,000 on the Kendall property, made an initial payment of $14,000 on the Shannon, now have about $200,000 in the treasury and recently declared the first dividend, payable Mar. 1, 1916.

This record has been the result of years of unceasing, intelligent labor in the face of ridicule and even of resentment among those petty people who never like to see a failure made good. During this time Charles W. Goodale, who was a director of the company at the time of its organization and collapse, has been the president and guiding spirit. The way in which he has raised this company from the depth of despair to the ranks of the dividend payers is a crowning achievement in the career of a distinguished and honorable mining engineer.

Copper at Highest in 40 Years

During the past week the price for copper rose to a higher figure than anything on record in recent history, and by recent history we mean to go back to the time of our Civil War and the years immediately following. In July, 1864, the average price for Lake copper at New York was 59¾c. per lb., and the average for the year 1864 was 46¼c. By May, 1870, the price had fallen to 19c., but in April, 1872, it was up again to 41¼c. These prices were made, however, in a period of depreciated currency and are not properly comparable with prices quoted subsequent to the resumption of specie payments in 1879. In 1873 the average price for copper was 29c. per lb. After that it was never higher than 25c. until March, 1907.

In March, 1907, Lake copper touched 26c. and electrolytic 25½c. Higher figures are talked about and probably were realized, but they were premium prices for relatively small lots for special delivery and were not representative of the broad market. However, at 25½@26c. some large sales were made. Yet those were but large sales, relatively speaking. On the upward movement of 1906-07, the great turnover occurred at lower levels. As the price for copper rose above 20c., the ability of producers to make sales rapidly diminished. After the climax in price had been attained, the market fell away rapidly.

The situation in February, 1916, just nine years after the previous great boom in copper, is totally different. The price for copper is not only strong and rising, but also producers are still able to sell all they can deliver. Whatever trouble there is at present is not inability of the producers to sell copper freely, but rather is it their inability to supply it at all.

Pan-American Papers

This issue of the *Journal* is devoted especially to the publication of technical papers that were presented in Section VII of the second Pan-American Scientific Congress, recently held in Washington, and that we are enabled to publish through the courtesy of the authorities of the congress. The papers themselves are of such high technical merit and wide variety that we need offer no apology to our readers for devoting this issue of the *Journal* almost entirely to them, although this has necessitated the omission of several of our regular departments.

It must be understood, however, that the papers published in this issue of the *Journal* are not all of those that were presented before Section VII, but are simply a selection of them. All of the papers then offered were of high class and great scientific value, and to Hennen Jennings, the chairman of the section, is due not only great credit for drawing them out, but also for his entire conduct of the very successful meeting.

New development in the steel trade seems to be unbalanced. The summary of new construction in progress published by the *Iron Age* shows that there are now building openhearth furnaces having a total yearly capacity of 4,265,000 tons of steel ingots, while only 11 blast furnaces having a yearly capacity of 1,750,000 tons of pig iron are under construction. That is, the additional supply of pig iron will be far less than the quantity required by the steel furnaces, even allowing for a liberal use of scrap. It takes longer to build a blast furnace than an openhearth furnace, and it looks as if some scarcity of pig iron might develop before matters are evened up.

The United States has passed Germany, heretofore the leader, in the number of electric furnaces used in making and refining steel. A year ago this country had 41 electric furnaces in use and Germany 46. The latest report gives Germany 53, while the United States has 73. This result is due to the war, at least in part. Naturally the war has not been favorable to new developments or new plants abroad, while here there has arisen a new demand for special steels which the electric furnace is well adapted to meet. It may be noted that the arc type finds most favor in this country, 68 furnaces being of that type, while five only are of the induction type.

Ocean freights at the beginning of 1916 showed an extraordinary increase as compared with 1914. According to a return recently presented to the British Parliament, rates from Bombay to British ports increased 596% and from Buenos Aires, 1,011%. Rates from Atlantic ports in the United States to Great Britain advanced 796% on grain, 803% on cotton and 775% on general mechandise.

PERSONALS

Mark P. Braffett has been elected president of the Salt Lake Stock and Mining Exchange.

Lawrence Addicks is gradually recovering from his recent illness and is at Atlantic City, N. J., for a rest.

Col. A. M. Hay, of Toronto, Ont., president of the McIntyre Porcupine Mines Co., has been visiting the property.

C. A. Foster, of Haileybury, Ont., has been in Toronto in connection with litigation over property at Kirkland Lake.

P. G. Lidner, of New York, has gone to Haiti on professional business and expects to be absent about three months.

T. B. Williams, engineer for the Canmore Coal Co., of Canmore, Alberta, has returned to the West after spending a month among his friends in Ontario.

Edgar A. Collins, who has been General Superintendent of the Commonwealth Mining and Milling Co., at Pearce, Ariz., for the last four years, has resigned, to take effect in March.

Edward F. Hasson, who was for five years manager of the General Specialty Co., Buffalo, N. Y., has become associated with the Advance Machinery and Supply Co., of Denver, Colo., as advertising and publicity manager.

The present officers of the Yellow Aster Mining Co. of California are: President, Albert Ancker; vice-president, E. D. Mooers; secretary, Dr. R. L. Burcham; superintendent, Carl H. Fry; managing director, W. J. Cotton; attorney, Ward Chapman; treasurer, the National Bank of California.

William Kennedy has resigned his position as geologist for the Southern Pacific lines in Louisiana and Texas, and has been appointed geologist for the Lone Star Gas Co., with headquarters at Ft. Worth, Texas. Mr. Kennedy has been at various times connected with the geological surveys of Arkansas and Texas and the United States Geological Survey.

At a meeting of the directors of the Yellow Aster Mining Co. at Los Angeles, Calif., Jan. 21, Ed. D. Mooers, second vice-president, was chosen first vice-president to succeed C. G. A. M. de Pauw, who has ceased to be connected with the company in an official capacity. Mr. Mooers is a son of the original locator of the Yellow Aster, and has had long experience in mining.

William L. Saunders, president of the A. I. M. E., gave a long interview to the "New York Times," which was published in the Sunday supplement of Feb. 6, entitled "Lining Up American Industries for Defense." The article contained a detailed description of the purposes of the industrial committee to be appointed as a coöperative part of the Naval Consulting Board, of which President Saunders is a member, and also a discussion of the dependence of this country on the Chilean nitrate field for the raw material for the manufacture of nitric acid, which is the base of all military explosives.

OBITUARY

Frederick J. Falding, the well-known chemical engineer, died in New York, Feb. 7. We expect to publish a fitting obituary in our next issue.

Edward N. Magner, president of the Aurora Mines Co. of Nevada, died at Los Angeles, Calif., Jan. 1, aged 57 years. He was born at Paris, Ill., and went to Colorado when a young man. He was active in the Leadville District and also at Creede. He was at Silver City, N. M., and later at Salmon City, Idaho, before going to Nevada.

Martin Quinn, foreman of the Charles Butters plant in Sixmile Cañon, died at Virginia City, Nev., Jan. 28, of paralysis. He was a native of Gold Hill and had spent nearly all his life on the Comstock. He was an expert millman and machinist and for several years was employed at the Mexican mill. He was also employed at Manhattan and then returned to Virginia City and to the Butters plant.

Col. T. L. Ayres died at Oakland, Calif., Feb. 1, aged 87 years. He was born in Baltimore, Md., and as a young man just through college joined the gold rush to California in 1849, crossing the plains with a brother of Mark Twain. The winters of 1851 and 1852 were spent in the vicinity of Emigrant Gap. Then Ayres went further north, and on his pack animal carried the first sack of flour into Siskiyou County, where he was a successful mining operator for many years. Nearly all the mining regions of the state knew him as a mining expert. In 1873 he married and went to Arizona, where he took up mining claims that are recorded among the most valuable holdings of that state. He lived in Mohave County for 30 years. In 1903 he retired from business and returned to San Francisco to spend the remainder of his life. He is survived by his two children, Edwin T. Ayres and Mrs. Morris Schneider.

Samuel Green, the New York capitalist, who arrived at Murray, Idaho, Jan. 21, died there Jan. 26 of heart disease. He owned the Golden Chest mine, near Murray, and had come from the East with the intention of giving his personal attention to the development of the property. The discovery of tungsten in the Golden Chest suddenly gave value to a gold mine that had been worked with indifferent success and for many years had been closed down altogether. Since that discovery several shipments have been made by express from which handsome returns are said to have been received. The first shipment was 55 sacks, which netted a little more than $11,000. Since then there has been a great advance in the price of tungsten, and the last shipment, returns for which were received after Mr. Green's arrival here, netted $52 per unit of 20 lb. Most of the ore that is now being taken out is from the old stopes where it was left years ago when the mine was being worked for gold. Twenty men are employed, and it is announced that the death of Mr. Green will not interrupt operations. Vivian Green, of New York, son of the deceased, succeeds to the ownership of the property.

SOCIETIES

Idaho Mining Association—A meeting was held at Boise City, Idaho, Jan. 25. The subjects for discussion were prospecting, leasing of claims and revision of the mining laws.

Leland Stanford Junior University—The Department of Geology and Mining at Palo Alto, Calif., has organized and is giving during the present term a special course on flotation. This is a three-hour course and covers the whole subject, including laboratory work. Special experiments in connection with flotation have been carried on at several schools, but it is claimed that this is the first regular course announced.

Society of Chemical Industry—A meeting of the New York section was held at Rumford Hall, New York, on the evening of Jan. 21. The program for the evening was the presentation of the Perkin medal to Dr. L. H. Baekeland, and included introductory remarks by W. M. Grosvenor, the chairman; presentation of the Perkin Medal and address by Charles F. Chandler; acknowledgment by the recipient of the Perkin medal, L. H. Baekeland.

American Institute of Mining Engineers—The Montana Section held its annual meeting on Friday, Feb. 4, at the Silver Bow Club, Butte, Mont. The usual informal dinner for men preceded the meeting. The business meeting for the election of officers, etc., was held at 8:30 p.m. in the parlor of the club. The business meeting was followed by a paper entitled: "Present Status of Oil and Gas Prospecting in Montana," by D. C. Bard and Chester Steele.

American Institute of Mining Engineers—The program for the 112th meeting, in New York, Feb. 14-17, provides for technical meetings Feb. 14 in the morning on petroleum and gas; in the afternoon on coal and coke and on geology. Feb. 15, two technical sessions, morning and afternoon. Feb. 16, sessions on iron and steel, morning and afternoon, and in the morning also on precious and base metals. The annual dinner will be held Feb. 16. On Feb. 17 there will be an excursion on a naval boat to the Navy Yard and the Sandy Hook proving grounds. A special program is provided for the entertainment of visiting ladies.

Canadian National Clay Products Association—The 14th annual convention was held at the King Edward Hotel, Toronto, Jan. 18-20, with a good attendance, President J. Edward Frid, of Hamilton, Ont., occupying the chair. An official welcome to the city was extended by Mayor Church. The visitors inspected the new clay products and construction laboratories of the Toronto Technical School. Officers were elected as follows: President J. Edward Frid, Hamilton; first vice-president, A. F. Greaves-Walker, Ontario; second vice-president, Thomas Kennedy, Swansea, Ont.; third vice-president, William Burgess, Todmorden, Ont.; secretary-treasurer, Gordon C. Keith, Toronto; councillors, C. B. Lewis, Milton, A. Lochrie, Toronto; A. Neil, Kingston; John S. McCannel, Milton; Ryland New, Hamilton; T. Graham, Inglewood, and W. Clarke, Sarnia. A resolution was adopted urging the Canadian government to establish a central bureau, where accurate information may be obtained as to the qualities of building materials.

Editorial Correspondence

SAN FRANCISCO—Feb. 1

The Pan-American Petroleum and Transport Co. incorporation is reported in San Francisco to have been filed at Wilmington, Del., on Jan. 31. Capitalization, $150,000,000. E. L. Doheny, president and chairman of board of directors; H. G. Wylie, of New York; M. L. Requa, of San Francisco; J. M. Danzinger, E. L. Doheny, Jr., C. E. Harwood, T. J. O'Donnell, of Los Angeles, are directors. The incorporation includes Mexican Petroleum Co., Ltd., of Delaware; Petroleum Transport Co., which owns the ships used by the Mexican Petroleum Co.; Caloric Co., marketing agent in South America; Buena Fé Petroleum of California, which controls oil lands in California and Texas. It is expected that the following named companies will also be included in the incorporation. California Petroleum Corporation, Union Oil Co., Associated Oil Co., General Petroleum Co., Independent Oil Producers Agency. One of the purposes announced is to eliminate waste which has accompanied the development of oil fields in the Middle West. In the drilling of wells and development of unexpected gushers, there is unnecessary multiplicity of means of collecting and storing oil and constant waste which, in the aggregate, it is claimed by the incorporators, amounts to a large percentage of the value as well as the production. There is no doubt that a merger of oil companies and the operating of various fields and manufacturing plants and transportation equipment under one general head and one board of directors will greatly reduce, not only the amount of waste, but the cost of operation. It is believed that the interests of Independent Oil Producers will be greatly enhanced by inclusion in this merger. When the Independents accepted the good offices of the Union Oil Co. of California they found that they had better facilities and advantages for meeting the competition of the Standard and the Dutch-Shell, because the Union had always been looked upon in the light of an Independent; but still the Union and the Independents were not so tightly bound together as they will be after they become a part of this new incorporation. The complete organization and practical operation of Pan-American Petroleum and Transport Co. will no doubt result in forming a sufficiently strong competitive concern as to assure the oil producers a fair chance and profitable outlet for their production. At one time, prior to the investigation by the U. S. Bureau of Corporations, the oil production in California was dominated by the Standard and the Southern Pacific. Conditions for the Independent producers were improved following the investigations and again received some further encouragement by the advent of the Dutch-Shell interests into the California fields; and still again the Independents were benefited by coöperation with the Union. Should all the operators and interests here mentioned be included in the new incorporation, it is believed that oil-producing and refining and marketing industries will be placed upon the solidest foundation since the beginning of commercial production of oil in California.

DENVER—Feb. 3

Cripple Creek Mines Produced during January 79,794 tons of ore having gross estimated bullion value of $1,207,543. The average grade treated in mills and smelteries outside the district was about $15 per ton. More than half the gold in the district's production was recovered in the Golden Cycle plant at Colorado City where the ore averaged nearly 1 oz. per ton. The two mills of the Portland company at the mines handled more than 30,000 tons of $2.04 ore.

Snowslides are unusually large, numerous and destructive this winter in the higher ranges. An avalanche struck the Gold King buildings at Gladstone (above Silverton), Jan. 29, causing heavy destruction. It missed, by only about 20 ft., the bunkhouse where 84 men were housed. Another slide wrecked the transformer house and blacksmith shop at the Liberty Bell mine above Telluride, same date, missing the bunkhouse by only 100 ft. A report says that a 6-ft. vein of tungsten ore was uncovered in Cement Creek Gulch, San Juan County, by a terrific slide.

BUTTE—Feb. 3

Montana Frisco Mine near Tower, Granite County, is to be unwatered at once preliminary to resumption of active operations. Machinery to drain workings is now being installed as well as new hoisting plant. D. M. Drumheller, of Spokane, is in charge of operations.

In the Troy Mining District, Lincoln County, extensive preparations are being made for resumption of operations at a number of promising lead, silver and zinc properties. Principal property is the Banner & Bangle, where 60 men are employed in development work. Tonnage developed of lead and zinc ores is valued at $3,000,000. Dam is being constructed across Callahan Creek to furnish hydro-electric power for a 6-mi. railway from property to Troy and for a mill to treat output. Work will mean employment of from 800 to 1,000 men next summer. Togo company has been organized to take over Togo group, consisting of 22 claims, for consideration of $75,000. Development work has encountered vein carrying 18 in. of shipping ore. Average samples assayed 71% lead, 15% copper and 26 ounces in silver. Big Eight group is to be reopened and exploited for its zinc deposit.

SALT LAKE CITY—Feb 4

The Salt Lake Stock and Mining Exchange during January traded in 3,485,548 shares of stock, valued at $562,982. This is an increase of $83,252 as compared with December. Interest in mining stocks and trading appears to be increasing, and attention is being given to many of the lower-priced shares. Each succeeding week in January trading was heavier. Sales for the week ended Jan. 29 amounted to 1,173,599 shares, with a valuation of $145,315. Due to the increasing business the board of governors decided to begin the afternoon call at 1 o'clock instead of at 1:30, starting Jan. 31. The question of confining the trading on the floor to the listed stocks only is being considered, which would make a curb market necessary for the unlisted stocks. Bids of $650 for seats on the Exchange are reported.

KELLOGG, IDAHO—Feb. 1

The New Scale of Wages at the Bunker Hill and associated mines, including the Caledonia and the Ontario, was announced in bulletins posted today. The base wage is the old scale of $3 per day for muckers, common laborers and oilers, and $3.50 for miners, millmen, etc., which will prevail in the future when lead averages less than 5c. for the preceding month. When the average price is between 5c. and 5½c., each employee of the company, irrespective of his position or salary, will receive a bonus of 25c. per day. With lead between 5½ and 6c. the bonus is 50c., and over 6c. it is 75c. per day. Since, according to the company figures, the average price of lead during January was 5.94c., the bonus for February will be 50c. Officials of the Stewart mine have announced that they will grant their employees the same bonus as that given by the Bunker Hill. Nothing definite has been heard from the other mines of the district, but it is reported that the Hecla will also adopt the Bunker Hill scale.

HOUGHTON, MICH.—Feb. 4

Onondaga Has Come Into the Nonesuch Formation—or the White Pine lode as it now generally is designated—there is every reason to believe. The result of the seventh diamond-drill hole indicates the swing of the lode and this verifies the geological theory of President R. C. Pryor, of the Onondaga, when he commenced the work.

Plans for the Reopening of the Oneco Property have been considered, but as yet no action has been taken. There has been considerable talk among some of the shareholders of the company to sell the Oneco to the New Baltic or New Arcadian simply with the thought of getting activity, shareholders feeling that something ought now to be done if ever. On the other hand, there is a feeling that the work which the New Baltic and New Arcadian is doing has great value with respect to the future of the Oneco and that this can be gained at no expense to the Oneco shareholders.

GOLDFIELD, NEV.—Jan. 30

Potash Alum, near Silver Peak, Esmeralda County, is to be exploited by Victor Barndt and associates of Tonopah. Leaching and calcining is expected to give a 60% K_2SO_4 product. Property is 1½ mi. from the Blair railroad and 11 mi. from Blair Junction.

TORONTO—Feb. 5

To Encourage the Small Prospector the Quebec government has introduced in the provincial legislature a bill to amend the Quebec mining law. The most important feature is the reduction of the minimum size of mining concessions from 100 to 40 acres. Other amendments provide for agricultural operations on lots found unproductive in minerals.

The Mining News

ALASKA

ALASKA MEXICAN (Treadwell)—In January, crushed 19,425 tons ore, of total gross value of $29,750. Operating expenses, $25,931.

ALASKA TREADWELL (Treadwell)—Ore crushed in January at 240 mill, 31,878 tons, at 300 mill, 48,815 tons. Total gross production, $141,866. Operating expense, $99,112.

ALASKA UNITED (Treadwell)—In January R-B mill crushed 24,780 tons ore; total gross value, $46,295. Operating expenses, $32,425. The 700-Ft. Claim mill crushed 23,730 tons; total gross value, $45,585. Operating expense, $38,240.

ARIZONA

Gila County

BLECHER (Globe)—Large body of $20 gold ore has been developed on Blecher group in the Pinal Mountains, 5 mi. from Globe. Ledge is 4 to 6 ft. wide and extends across 3 claims. Two tunnels have been driven on bottom level of 100-ft. shaft a distance of 40 and 60 ft. respectively in ore. Two inches of vein runs from $40 to $150 in gold.

COWBOY (Globe)—C. W. McGraw, owner, is now in California, where it is thought he will purchase cyanide plant. Mine in Dripping Springs Wash has recently produced some rich ore. Two tons shipped to San Francisco recently returned $2,800; one shipment of 45 lb. brought $1,500; three comparatively small pockets have produced $8,000.

INSPIRATION (Miami)—Company is making regular shipments of oxidized and siliceous ores from its claims formerly owned by Cordova Copper Co. to the International smeltery. New units going into operation at concentrator necessitated mines working seven days a week. Engines and 5-ton cars now in transit will supplement underground haulage; 40-in. circular saws have been installed on two levels.

Mohave County

SHOOTING STAR (Golconda)—Kingman Zinc Co. will soon begin stoping above east and west drifts on 130 level. Ore exposed averages 2 ft. in width and assays 20% zinc, $5 gold and $3 silver. Shipments will soon be made to company's Cupel mill, 1 mi. distant, which has recently been overhauled.

ARIZONA VENTURE (Cedar Valley)—Company will increase scale of operations at Waldron group. Shaft now down 350 ft. will be continued to depth of 500 ft., with lateral explorations on 415-, 450- and 500-ft. levels. Special attention will be given to production of crystals (lenzite) for wireless telegraph. Recent shipment of 256 crystals to English Government brought $10 apiece. Waldron ore also contains gold, silver, copper and lead.

Pima County

GOLD BULLION MINES (Tucson)—Company is mining and treating 25 tons daily molybdenum ore from Last Chance shaft on property in Baboquivari Mountains, 65 mi. southwest of Tucson. Property consists of 24 claims, on which about 4,000 ft. of development work has been done.

COLONIAL COPPER (Ajo)—Decree foreclosing deed of trust securing bond issue of $172,000 from Beacon Trust Co., of Boston, was entered by Judge W. A. O'Conner, sitting in Superior Court at Tucson. Allen B. Janes, receiver for company, was ordered to sell property, consisting of 26 patented claims in Grawler Mountains, 16 mi. southwest of Ajo. Sale will be held on ground, Mar. 22.

Yavapai County

BLUE BELL (Mayer)—Largest Deposit of copper ore in property has just been discovered on 800-ft. level. New body runs 6%; 250 tons daily output now.

RUTH (Prescott)—Three tons of lead concentrates and nearly as much zinc was result of first four-day run of new mill. Lead concentrates assayed 55% and zinc 37%. Zinc recovery 94%; mill is running on 500-ton dump of second-class ore.

Yuma County

BOUSE & McMAHON (Bouse)—Mine of 12 claims sold to M. D. Murray and Fred Fenchler, of El Paso.

BLUE STATE (Midway)—Group of 6 claims and Dutchman group of 13 claims recently taken over by Fenchler, Murray & Fenchler, of El Paso, are situated in Palomas district, about 20 mi. east of Colorado River and about 50 mi. south of Oatman. There are 2 shafts on property, about 55 ft. each, and 30-ft. drift.

CALIFORNIA

Amador County

IONE BRIQUETTING (Ione)—Demand for this fuel necessitated operation in 3 shifts instead of 2, as heretofore.

AMICK CLAY (Ione)—Property has been inspected by W. M. Moore, president of the California Products Co. of San Francisco, who is reported to have stated that clay is especially valuable for manufacture of fireproof paint. Product has been going to Stockton Glass Co., at Stockton, but recent rains and snow have made wagon haul to railroad difficult.

OLD EUREKA (Sutter Creek)—Report persists that T. Walker Beam and J. D. Gilchrist, Colorado mining men, have examined this property with view to purchase by men who will reopen and develop it. It is reported also that same men who are said to be negotiating for Old Eureka have also considered adjoining mines, known as Wildman-Mahoney. Wildman was one of large producers in early history of Mother Lode mining. Property was developed by 1,400-ft. incline shaft and a 600-ft. vertical shaft, from which drifts were run into orebodies.

Calaveras County

PIONEER CHIEF (San Andreas)—New 2-compartment shaft is down 320 ft. and work is being advanced with air drills in 3 shifts. Shaft will be deepened to 500 ft. and stations cut on 350 and 500 levels. Drifts at 220 level have been advanced 175 ft. south and 165 ft. north on good ore. Installation of 100-ton mill contemplated. Electric power is taken by pole line from main transmission plant of Electra Power plant. Head office of company is in San Francisco.

Eldorado County

GEORGIA SLIDE (Georgetown)—Machinery for development and exploration continues to arrive on ground. The 10-stamp mill of Cambrian mine will be moved to Georgia Slide. Work has been delayed by bad roads and bad weather.

CROWN-POINT (Placerville)—J. Newton Judson, recently operating W. E. Jones mine, in Ringgold district, has taken bond on Crown Point and Gold Queen, owned by James Richards, in East Diamond district. Property has been fairly well developed and has produced large amount of low-grade ore. There is 500-ft. shaft with levels cut at two stations.

MONTEZUMA (Nashville)—Unwatering has been practically completed and deepening of 700-ft. shaft to total depth of 1,200 ft. will begin without delay. Ore of good grade reported disclosed in upper levels, but extraction of ore will await completion of the shaft. This is one of properties being reopened on Mother Lode by Bewick, Moreing & Co.

Kern County

ANTIMONY ORE reported in Kern River district by Barney Parker, of Fresno. Samples assaying about 45% were taken from 4-ft. ledge.

SUNSHINE & MERCED (Randsburg)—Petition for leave to lease these properties filed by O. P. Atkinson. Property is part of Thomas W. Atkinson estate. It is proposed that Sunshine be leased for one year on 15% royalty and Merced on 10%.

CONSOLIDATED (Randsburg)—Under management of Seth Tyler, there is evidence that mine will again be put in producing class. Good vein showing free gold has been opened on 400 level in west drift. Ledge is from 2 to 4 ft. wide and ore assays about $30. This is new ground and it is believed that an extensive orebody will be opened up.

YELLOW ASTER (Randsburg)—At meeting of directorate Jan. 2, E. D. Mooers was elected first vice-president to succeed C. G. A. M. de Pauw, who severed his official connection with conduct of mine. Mr. Mooers is son of one of original locators of Yellow Aster. The present officers are now in control: Albert Ancker, president; E. D. Mooers, vice-president; Dr. R. L. Burcham, secretary; Carl H. Fry, superintendent; W. J. Cotton, managing director; National Bank of California, treasurer; Ward Chapman, attorney.

Nevada County

BRUNSWICK (Grass Valley)—The "jinx" has been removed and Superintendent Mallen believes that property will now perform normally. First a large motor operating pumps and hoists burned out and parts required could be got only in New York; then water situation became serious and this source of power was shut off. Just as relief was in sight, a 1,500-lb. shafting broke, causing further delay and complications. Motor has been repaired, water is running placidly, big shafting is again in order and whole equipment of mine and mill is running as smoothly as though "jinx" had never made his appearance.

San Bernardino County

ATOLIA MINING (Atolia)—Work of rebuilding the mill, which was partially destroyed by fire, has been begun and it is understood that in new construction, capacity will be increased from 100 to 200 tons.

SPANISH LEASE (Atolia)—Atolia company is working this ground and producing best ore in camp. About 60 men are employed and new ground is being rapidly developed. About three months ago shaft was deepened and only small amount of drifting done, which disclosed some good ore. Since that time improvements have been made to surface equipment and property is now one of most valuable producers operated by company. Operation also undertaken about 100 ft. from main shaft.

Shasta County

EL ORO DREDGING (Redding)—Company has shipped Keystone drill and will begin prospecting ground along Sacramento River on east front of town. Option has been taken on about 400 acres, most of it known as Dakin tract. Company operates dredges at Oroville, Jenny Lind and Yreka.

Tuolumne County

McCORMICK (Jacksonville)—Development in steady progress by Albert and Charles Murphy, working under lease. The 1,400-ft. tunnel will be advanced to point below bottom of 50-ft. shaft. Development by shaft disclosed number of shoots of pay ore which it is believed will be tapped by tunnel. Plane of tunnel is 1,500 ft. higher than river.

COLORADO

Boulder County

BRACKEN (Boulder)—This property, which includes Good Friday, April Fool and Red Bird mines, near Boulder Falls, is developing promising bodies of tungsten ores. Main shaft is being sunk in payable ore. Compressor and hoisting plants are being installed and power line is being built to connect with lines of Colorado Power Co. Property is owned and managed by C. C. Bracken.

Ouray County

CAMP BIRD (Ouray)—Will drive 10,700-ft. adit, 450 ft. below present deepest workings and 800 ft. below workings next most important. Careful estimate of cost exclusive of administration will not exceed $200,000. Time required estimated 27 months.

San Miguel County

CLIFF DWELLER (Norwood)—G. G. Galloway has granted 2-yr. bond and lease on this property to A. McCloud and associates, who will commence development work Apr. 1.

RADIUM ORE ASSOCIATION (Placerville)—Is new organization formed recently by carnotite miners of Paradox Valley to market and get fair price for carnotite ores produced. Following officers have been elected: Thomas Curran, president; E. W. Bray, 1st vice-president; William Sullivan, 2nd vice-president; Joseph H. Jackson, of Placerville, secretary; and G. G. Galloway, of Norwood, treasurer.

SILVER CHIEF. (Telluride)—This property, on west side of Bear Creek Gulch, about 2 mi. south of Telluride, is reported sold by Alva Adams et al. to G. M. Weeks and Associates, of Chicago, for $150,000. Purchasers have also acquired properties of Junta Consolidated Gold Mining Co., including Jim Crow mine and Junta mill, in Bear Creek Gulch. New company plans campaign of development and intends to place mill in commission as soon as possible.

Teller County

DELMONICO LEASING (Victor)—New company, to be managed by J. De Roucha, has secured 5-yr. lease on Delmonico mine, on western slope of Bull Cliff and east of Deadwood No. 2 of United Mines Co. Preparations being made to start work; machinery being overhauled and shaft house being repaired. Shaft has been sunk to depth of 1,100 ft. and about 5,000 ft. of lateral development performed. The new company will commence development work on 600 and 1,100 levels.

IDAHO

Shoshone County

REX (Wallace)—Diamond-drill hole run south from No. 2 tunnel shows 7 ft. commercial ore in parallel vein at depth of 500 ft. New vein will be further explored by drill hole 300 ft. below 2 level.

CALEDONIA (Kellogg)—Company reports 7 ft. of shipping ore on the 1,000-ft. level and about the same amount of milling. Ore runs high in silver and also carries above 2% copper and some lead. Report for December shows gross value of ore shipped $125,481, of which $48,468 was lead, $61,868 was silver and $15,145 was copper.

CŒUR D'ALENE ANTIMONY (Kellogg)—This company has recently completed mill to which is now being added flotation. Drift from shaft at depth of 150 ft. has opened oreshoot 300 ft. long, averaging 3 ft. wide, all excellent milling ore. Shaft being extended and new level will soon be opened at 300 ft. Company employs 50 men.

CASTLE ROCK (Wallace)—Three men were buried by snowslide but escaped serious injury at this Placer Creek property. Long section of flume was carried away, three cabins were destroyed, and corner of compressor house was wrecked but without injuring machinery. No attempt will be made to resume operations till spring.

SUCCESS (Wallace)—According to statement of P. J. Gearon, general manager, Success mine has ore reserves for 18 months. Development during 1915 included 1,375 ft. of drifts, 200 ft. of shaft, two working stations, and sump station on 1,200 level. Ore on newly developed 1,200 is as good as any in mine. Plans for 1916 include exploration on 1,200 and sinking to 1,300.

STEWART (Kellogg)—This mine, currently reported to be almost exhausted, is making extensive explorations on old Silver King and Crown Point properties, obtained last year through purchase of controlling interest in Cœur d'Alene Development Co. Silver King shaft is being retimbered and will be sunk to 500 level. In Crown Point, hoisting machinery has been installed and one to three cars of milling ore is mined daily.

MICHIGAN

Iron

OHIO (Michigamme)—Operations to be resumed. Mine has not worked for several years. Last of ore, limonite, in stock was shipped in 1915.

TRADERS (Iron Mountain)—New shaft now down 110 ft. Most of new equipment has arrived. Contract to strip 50,000 cu.yd. to be let soon.

HOLMES (Ishpeming)—Steel headframe with crushing plant will be constructed. Ledge has been struck in shaft. Water was encountered at 13 ft.

RICHMOND (Palmer)—Electricity is to take place of steam here. Hoist, compressor, etc., will be electric driven. Mine is worked only during winter months.

BERKSHIRE (Iron River)—Contract awarded to Sullivan Machinery Co., Chicago, for two electric hoists and electric-driven compressor. Delivery will be made in 100 days.

SPIES (Iron River)—Shaft work going ahead rapidly. First level will be started at 150 ft. Most of equipment will be from Lucy mine, Negaunee, now on the ground. Steel headframe will be erected; will contain a crushing plant.

ATHENS (Negaunee)—Shape of the shaft has been changed from circular to rectangular to make sinking more rapid. Less rock will have to be handled. Shaft is now down about 1,300 ft. and concreted all the way. It will go about 2,400 ft.

MINNESOTA

Cuyuna Range

CUYUNA-SULTANA (Ironton)—Engineers at work on plans for concentrating mill to be erected during coming summer.

Mesabi Range

IRON MINING (Virginia)—Has donated a considerable quantity of mine timber to Associated Charities to be used in municipal woodyard.

CHISHOLM (Chisholm)—Sudden change in wind affected air circulation in part of mine's workings to such an extent that Joe Gasparac, a miner, was overcome by gas arising from decayed timbers. Accident is unique in district.

MONTANA

Cascade County

GREAT FALLS REDUCTION WORKS (Great Falls)—In spite of zero weather work on new zinc plant is kept going; 100 men are doing excavating work day and night. Clifton-Applegate company has contract for preliminary work. Within past few weeks 50,000 cu.yd. of earth have been removed by steam shovels. First shipment of 2,000,000 brick has arrived. Contractors state their work will be completed by middle of March.

Silver Bow County

RAVEN COPPER (Butte)—Shareholders of this company whose Butte property was recently acquired by the Anaconda company, are realizing on their holdings, following the order of State of Maine Supreme Court by which company was dissolved Dec. 9, 1915. Court ordered trustees to distribute among stockholders sum amounting to 26c. a share. At one time Raven stock was held at $8 a share.

BULLWHACKER (Butte)—Arrangements have been made by new management for handling of its ore by Tacoma smelter at profitable smelting rates. Cold weather has prevented resumption of operations so far. In meantime tests are being made with object of perfecting leaching process in existing plant which, if successful, will permit operators to treat ore at mine and become independent of smelters.

DAVIS-DALY (Butte)—Rumors of a contemplated assessment of company's stock to raise funds for increasing operations at company's Butte properties were set at rest by news received from company's headquarters to effect that $50,000 had been secured in Boston. This will permit purchase and installation of new hoisting engine, recently recommended by Secretary Schirmer. With improvements completed in shaft management has reopened 1,400 intermediate, 1,500 and 1,700 levels, and production will be increased as soon as new engine is ready for operation.

BUTTE & SUPERIOR (Butte)—An accident that did some damage but did not injure anyone compelled company to close down mine Jan. 29. One of big 5-ton skips was being hoisted in shaft when it broke away and fell into sump, tearing out several timbers in its descent. Damage was quickly repaired and on night of day following accident operations were resumed. According to figures given out by company Feb. 1, output for January was as follows: Tons of ore mined and milled, 54,000. Tons of concentrates from ore, 14,800. Pounds of zinc in concentrates, 15,700,000. Payroll for January was approximately $240,000. Number of men employed at present, 1,850.

NEVADA

Storey County

ANDES (Virginia)—Worked two days only on account of storm; broke down ore and stoped.

ALPHA & EXCHEQUER (Virginia)—Face of joint west drift on boundary line in hard quartz of low assay and advanced 5 ft. to the 116-ft. point.

SIERRA NEVADA (Virginia)—Saved from raise in old stope on 2,400 level 53 tons of ore averaging $9. West crosscut on 2,500 level in vein matter and clay, quartz of fair assay; bottom of winze No. 1 stope, in low-grade ore at 24 ft. point.

MEXICAN (Virginia)—West crosscut on 2,500 level in porphyry, clay and quartz stringers, of low assays. Mexican mill shut down five days on account of delayed shipments of zinc dust and fuel oil, caused by storms. Crushed 103 tons custom ore averaging $10.81.

UNION (Virginia)—Only small amount of ore extracted because Mexican mill shut down five days; 50 tons averaging $12.38 per ton taken from No. 4 stope on 2,400 level. Development in stope and preparations for stoping continued. Shaft reopened to 120-ft. point below 2,000 station; 15 ft. made in the week.

OPHIR (Virginia)—Resumed work at Central tunnel and advanced drifts in tunnel and 250 level. Saved 130 cars of ore. Mill resumed operation. Ophir and Con. Virginia joint west crosscut on 2,700 level advanced through soft vein formation of clay and quartz stringers. Crosscut advanced to 305 ft. point from winze.

CROWN POINT-BELCHER (Gold Hill)—Saved 261 cars from No. 2 stope 1,600 level. Repairs made in joint incline 1,400 level and to Jacket shaft. Jacket mill run four days, being closed on account of storms. Received 94 tons dump rock and 517 tons mine rock; shipped 310 tons to gloryhole from mine. Shipped two bars bullion to smeltery.

NEW MEXICO

Grant County

MOGOLLON M. & M. (Mogollon)—Together with Mogollon Mines, company made express shipment to New York of gold ingots, valued at $54,000—result of several weeks' cleanup.

EMPIRE ZINC (Hanover)—Now building new electrostatic concentrator on Hanover property exactly like concentrator recently erected on its Cleveland group, at Pinos Altos. Large body of zinc sulphides will be put through new mill. Hope to have mill ready by middle of year; will probably treat custom ore also.

GOLD BRICK NOS. 1, 2 AND 3 (Steeplerock)—Recently bought from Ollie Phillips, original owner, by D. A. McDonald, representing San Francisco syndicate. Property is gold bearing and adjoins Imperial group, 12 mi. north of Duncan, Ariz.

Taos County

TAOS MINING (Taos)—Company organized under laws of Delaware, with capitalization of $2,000,000, to operate copper, gold and silver properties in Twining district, has been admitted to do business in New Mexico. A. Clarence Probert, of Taos, statutory agent; J. B. Bidwell, of Twining, vice-president and mine superintendent.

TEXAS

Brewster County

BIG BEND (Terlinguia)—Has been unwatered and is being reopened by W. D. Burcham. Fifty-ton furnace started; 300 flasks quicksilver per month expected; year's supply ore blocked out.

CHISOS MINING (Terlinguia)—Company produced 1,200 flasks of quicksilver during November and December, 1915. Rotary furnace supplementing 18-ton shaft furnace will soon be installed. This will greatly increase output; also will make possible treatment at profit of large quantity of low-grade ore, hitherto unprofitable. Wayne Cartledge, manager; 150 men are employed.

UTAH

Beaver County

NORTH AMERICAN (Minersville)—High-grade silver-lead ore has been opened on 180 level. Property adjoins Creole and Croff on south. Charles Morrison is manager.

CEDAR-TALISMAN (Milford)—In last eight months this company has shipped enough zinc ore to pay its debts, put in new electrical equipment, and develop property. Sales of zinc ore in 1915 amounted to $9,326.

CREOLE (Milford)—This property—under lease to Dern & Griggs—has in neighborhood of 200 tons of ore broken for shipment. Eight men are working in ore. Material carries copper, silver, gold and iron. Lumber for buildings, assay supplies, etc., have been ordered.

CROFF (Milford)—Stock of this company listed on Salt Lake Stock and Mining Exchange; application for listing showed property to be well equipped and free from debt. Capitalized at 1,000,000 shares, par value 10c. There are 295,000 shares in the treasury. Holdings consist of five patented claims in Lincoln mining district, 12 mi. from railroad. Development so far consists of 750 ft. of shaft work and 665 ft. in drifts and tunnels. Six men are working. J. B. Leggat is consulting engineer. Hoist is being installed. Initial shipment from Lucky Boy shaft carried zinc, lead and few ounces of silver.

MAJESTIC (Milford)—Shipments during past two months amounting to 43 cars or over 2,000 tons, were made. Most of output comes from Old Hickory mine, from large open cut. Ore is contact deposit between monzonite and limestone, and carries large amount of magnetic iron. Some zinc ore is being hoisted at Harrington from 160 level, and one shipment has been made. At Hoosier Boy drifting has been done on fissure on 600 level, and shipment of ore carrying lead and silver is being made from this ground. There are 40 men working at different properties of this company.

Juab County

IRON BLOSSOM (Silver City)—New body of copper ore opened by winze from 600 level, has been drifted on, on 1,000 level. Hoist will be installed at winze so that ore can be followed to greater depth. New body is under Van stope, one of largest in mine, and at present productive.

YANKEE CONSOLIDATED (Eureka)—East tunnel which is being driven for continuation of Beck Tunnel vein is in 225 ft.; ore carrying up to 12 oz. in silver has been found. New orebody in western part of property has been opened 150 ft. on strike. Ore, which runs well in silver with some gold is being broken, and two cars weekly will be shipped when roads can be opened.

Salt Lake County

UTAH COPPER (Bingham)—Production for December amounted to 14,497,485 lb., bringing total output for 1915 to 156,207,563 lb. as compared with 121,779,716 lb. in 1914.

UTAH METAL AND TUNNEL (Bingham)—This company is adding to its surplus at rate of $75,000 to $100,000 a month. It is reported there is on hand $800,000, and that dividends will be started as soon as the reserve reaches $1,000,000. Company owns Utah Metal, and former Bingham-New Haven properties.

SOUTH HECLA EXTENSION (Alta)—Equipment consisting of mine cars, rail, air line and machine drills has been ordered, and as soon as these arrive work will be started from Quincy tunnel of South Hecla. Drifting will be started for known mineral-bearing fissures, which cut this company's ground.

SELLS (Alta)—Main orebody has been found again beyond fault in No. 1 raise workings. Ore had been followed 160 ft., when it was cut off. Raise found continuation of ore at 35 ft., and drifting in ore was again started. Total development amounts to 200 ft. on strike, and ore varies from 5 to 12 or 15 ft. in thickness. Shipments have been delayed on account of heavy storms. A foot of ore has been encountered in No. 6 raise, and this continues strong in southwest face of drift, which is being driven toward limestone-quartzite contact.

Summit County

DALY-JUDGE (Park City)—Last car of equipment for new hoist has arrived and will be installed as soon as possible.

NAILDRIVER (Park City)—Another car of ore has been shipped from this property in eastern part of camp.

IOWA COPPER-COPPER APEX (Park City)—A 4-in. streak of ore on quartzite-limestone contact is being followed in tunnel. Property is on Scott Hill in Thaynes Cañon section. D. Scott is foreman.

ONTARIO (Park City)—Unwatering of No. 3 shaft from 1,500- to 1,700-ft. level began Jan. 26. This portion of mine has been under water since 1905 when cave-in in long Ontario drain tunnel resulted in flooding mine. Tunnel was cleared in 1908, and mine unwatered to 1,500. There are stored at No. 3 shaft 850 tons of coal to provide fuel. Pumping is under way, and it is hoped to reach 1,700 level by middle of February. There is large amount of second-class ore, as well as some shipping ore, in territory being unwatered.

Tooele County

OPHIR HILL (Ophir)—Reported that this company is considering an increase in wages of its employees.

BUFFALO CONSOLIDATED (Ophir)—Recent strike in lower workings of this property on Lion Hill indicates that ore is improving with depth. Grade here is equal to that of ore which came from productive surface workings.

Utah County

WASATCH OZOKERITE (Cotton)—Incorporated to produce ozokerite, a mineral wax. Capitalization is $100,000. Property is at Soldiers' Summit near Colton. L. V. Shearer is president. Experiments toward the separation on a commercial basis of wax from gangue have been in progress for some time, and it is stated that satisfactory method has been discovered. It is planned to build plant at Soldiers' Summit.

VIRGINIA

Louisa County

ARMINIUS (Mineral)—The old workings caved during the latter part of January and affected both the No. 3, or operating, shaft, 1,200 ft. deep, and the new development shaft which was down 1,014 ft. Regular production will probably be stopped for three or four months. Miners are being employed on surface and deevlopment work.

CANADA

Ontario

DOME EXTENSION (Porcupine)—Shaft is being unwatered.

TRIUMPH (Porcupine)—Shaft will be sunk 100 ft. to 217-ft. level.

VIPOND (Porcupine)—Main vein has been crosscut on 400-ft. level.

SWASTIKA (Swastika)—This mine has been closed down and the pumps taken out.

KERR LAKE MAJESTIC (Cobalt)—Property and plant will be sold at bailiff's sale.

OPHIR (Cobalt)—Shaft will be put down further and additional machinery installed for deep development.

WEST DOME (Porcupine)—Richard Ennis, mine manager at McIntyre, has been placed in charge of development.

LENNOX CLAIMS (Boston Creek)—Have been purchased by Syndicate headed by W. H. P. Jarvis, of Toronto.

WRIGHT CLAIM (Cobalt)—This property adjoining Adanac is understood to have been purchased by the Cartwright interests.

R. A. P. (Boston Creek)—Is negotiating for sale of 75% interest in property to Montana, New York and Toronto capitalists.

TRIUMPH (Porcupine)—On this property, formerly Success, a shear zone has been encountered in crosscut on 100 level.

KING DODDS (Kowkash)—Which was the original discovery in this field is to be developed. Contract has been let for sinking and drifting.

APEX (Porcupine)—Shareholders ratified by-law authorizing directors to sell 699,991 shares of treasury stock at not less than 15c. per share to raise funds for development.

ADANAC (Cobalt)—An oreshoot carrying native silver has been struck at depth of 50 ft. in winze put down from 200 level. It is supposed to be vein coming in from Temiskaming.

DOME LAKE (Porcupine)—An orebody stated to assay $7 per ton encountered in raise from 300 to 180 levels. Crosscut is being run from shaft on 400 level to catch No. 1 vein. Equipment for new cyanide plant is on the way.

PORPHYRY HILL (Porcupine)—Property, formerly operated by Preston-East Dome, has been sold. Purchaser is stated to be Northern Syndicate, which is interested in number of Porcupine holdings.

DOMINION REDUCTION (Cobalt)—Has taken six-months' option on Big Master, Laurentian and H. B. 208 properties, in Manitou Lake gold area, which have been closed down for many years. Force of 18 men now at work unwatering workings and sampling.

MEXICO

Sonora

MONTECRISTO SONORA (*Moctezuma*)—Ore is being shipped regularly; runs about 500 oz. silver with some lead and copper. There has been no interruption during invasion of Villa army, but work is now progressing much better as they are now able to secure all the packers that they want.

MINNEAPOLIS COPPER (*Cumpas*)—Large force of men are at work building new trail and mining ore, which is being shipped to Douglas smelters. Having large amount of ore on dumps, this is being sorted and at the same time ore is being mined which will make production of about 10 tons a day. Ore runs 14% copper with some silver and gold. Is heavy sulphide ore and gets good smelting rate.

ASIA

Chosen

ORIENTAL CONSOLIDATED (*Unsan*)—Cable advices Feb. 3 give amount of January cleanup as $144,930.

The Market Report

Metal Markets

NEW YORK—Feb. 9

Further strength was exhibited in all of the principal markets during the last week, but especially in copper and lead. The markets for copper, lead and spelter are characterized by an absence of stock available for prompt delivery, but this is in varying degree.

Copper, Tin, Lead and Zinc

Copper—The opinion is expressed in the offices of producers that the stock of copper at refineries and in warehouse on Jan. 1, 1916, which last week we reported at 84,660,380 lb., included at least 30 million pounds that had been sold, but had not been shipped owing to the freight congestion. Since then the stock has without any doubt been reduced to a dangerously low figure, although there are still difficulties in shipping. We hear gossip about copper going to the Naugatuck Valley by express, and even by automobile truck.

During the last week the price for electrolytic copper moved upward day by day. The major market became the selling for delivery in the second half of 1916. Notwithstanding the fact that transactions had to be made for so far ahead, there was a fairly large volume of business in million-pound and two million-pound lots, mostly with domestic manufacturers. There was some relatively small business between belated consumers and such producers, traders, etc., as could supply near-by copper, for which premiums were demanded and paid, 27@27½c., r.t., being reported realized for prompt, with March, April and May at a scale downward. In the main the large producers are sold out, in some cases up to the end of May, and in other cases up to the end of June. Such copper for early delivery as becomes available through switching of contracts, etc., is supplied to regular customers at the same price as is asked for the later deliveries. The producers are doing everything they can to take care of their customers in this country, but ask and get premiums from foreign buyers.

In the English market the price for copper rose to £131.

Copper Sheets are again higher, being quoted at 33c. per lb. for hot rolled and 34c. for cold rolled. Copper wire is 27½@27¾c. per lb., in large lots at mill.

Exports of Copper for the week ended Jan. 22 are reported by the Department of Commerce at 17,023,245 lb. The chief items were 8,129,402 lb. to France, 4,179,625 lb. to Italy, 2,257,827 lb. to England and 1,571,604 lb. to Russia in Asia. Imports were 3,345,877 lb. metal and 310,751 lb. in ore and matte.

Visible Stocks of Copper in Europe on Jan. 31 are reported as follows: Great Britain, 8,751; France, 1,247; afloat from Chile, 3,525; afloat from Australia, 4,000; total, 17,523 long tons, or 39,251,520 lb.

Tin—A fairly good business was done, without any particular feature of interest.

Visible Stocks of Tin Jan. 31 are reported as follows: London, 5,234; Banka and Billiton, 1,091; United States, excluding Pacific ports, 10,716; total, 17,041 long tons. This is an increase of 825 tons over Dec. 31, and of 3,140 tons over Jan. 31, 1915. The statement includes tin afloat.

Lead—Many of the independent producers are entirely sold out. Others who still have some lead available endeavored to dodge domestic orders, being able to get premiums on Canadian and other foreign business. This led domestic consumers also to pay premiums to get what they wanted. Meanwhile the St. Louis market was advancing. It was the general belief that this situation foreshadowed an advance by the A. S. & R. Co. In the afternoon of Feb. 9 the A. S. & R. Co., after making large sales to domestic consumers during the two previous days, advanced its price to 6.25c., New York.

Spelter—This market was again in a chaotic condition, with prices at sixes and sevens, according to delivery, views of buyers and sellers, etc. The market advanced on relatively small transactions. Such business as could be referred to as tonnage was chiefly for April-May-June delivery, realizing 15½@15¾c. in the early part of the week, and 16¼@16½c. in the latter part. There were considerable sales for export.

Zinc Sheets are in steady demand and sales continue good. Prices are unchanged at $24 per 100 lb., f.o.b. Peru, Ill., less 8% discount.

IMPORTS AND EXPORTS

Imports and Exports in Great Britain of metals other than iron and steel, year ended Dec. 31, in long tons:

Metals:	Imports 1914	Imports 1915	Exports 1914	Exports 1915
Copper	178,905	205,385	50,778	33,117
Tin	40,961	38,896	44,242	37,506
Lead	224,916	256,476	50,943	67,906
Zinc	128,304	82,556	7,474	2,389
Quicksilver	1,263	1,359	769	436
Minor metals	6,825	5,385	23,919	18,864
Ores, etc.				
Tin concentrates	32,398	44,748	.....	.....
Pyrites	803,149	903,401	.....	.....

Copper includes metallic contents of ore and matte. Exports include reëxports of foreign material.

DAILY PRICES OF METALS IN NEW YORK

Feb.	Sterling Exchange	Silver, Cts. per Oz.	Copper Electrolytic, Cts. per Lb.	Tin Spot, Cts. per Lb.	Lead New York, Cts. per Lb.	Lead St. Louis, Cts. per Lb.	Zinc St. Louis, Cts. per Lb.
3	4.7575	56¾	25¼ @25¼ 25¾	41¼	6 10	6.00 @6.02½ 6.00	15.50 @18.50 15.75
4	4.7588	57	@26 25½	41¼	6 10	6.00 @6.02½ 6.00	15.75 @18.75 15.75
5	4.7575	57	@26 25¾	41¼	6 10 6.10	@6.02½ 6.02½	@18.75 16.00
7	4.7575	56¾	@26¼ 25¼	41½	@6 15 6.10	@6.05 6.02½	@19.00 16.50
8	4.7588	56⅝	@26¼ 26	41½	@6.15 6.15	@6.07½ 6.07½	@19.00 16.50
9	4.7600	56⅝	@26½	41½	@6.25	@6.17½	@19.00

The quotations herein are our appraisal of the average markets for copper, lead, spelter and tin based on wholesale contracts for the ordinary deliveries of the trade as made by producers and agencies; and represent, to the best of our judgment, the prevailing values of the metals, reduced to basis of New York, cash, except where St. Louis is given as the basing point. St. Louis and New York are normally quoted 0.17c. apart.

The quotations for electrolytic copper are for cakes, ingots and wirebars. Electrolytic copper is commonly sold at prices including delivery to the consumers and is subject to discounts, etc. The price quoted for copper on "regular terms" is the gross price including freight to the buyer's works and is subject to a discount for cash. The difference between the price delivered and the New York cash equivalent is at present about 0.25c. on domestic business. The price of electrolytic cathodes is 0.05 to 0.10c. below that of electrolytic. Quotations for lead represent wholesale transactions in the open market for good ordinary brands. Quotations for spelter are for ordinary Prime Western brands. Only the St. Louis price is herein quoted, St. Louis being the basing market. We quote the New York price at 17c. per 100 lb. above the St. Louis price.

Silver quotations are in cents per troy ounce of fine silver.

Some current freight rates on metals per 100 lb. are: St. Louis-New York 17c.; St. Louis-Chicago, 6.3c.; St. Louis-Pittsburgh, 13.1c.

LONDON

Feb.	Silver	Copper Standard Spot	Copper Standard 3 Mos.	Copper Electrolytic £ per Ton	Copper Electrolytic Cts. per Lb.	Tin Spot	Tin 3 Mos.	Lead £ per Ton	Lead Cts. per Lb.	Zinc £ per Ton	Zinc Cts. per Lb.
3	26 13/16	95	94¼	127	26.84	178¼	178¾	31	6.60	88	18.73
4	27 1/16	96	95½	128	27.25	180	180¼	31	6.60	88	18.73
5	27⅛	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	27 1/16	97½	97	129	27.47	179½	179¾	31¼	6.65	89	18.95
8	27	101½	100	131	27.89	179½	179½	32	6.81	89	18.95
9	27	100	99	131	27.89	179¾	179½	31¼	6.76	91	19.37

The above table gives the closing quotations on London Metal Exchange. All prices are in pounds sterling per ton of 2240 lb., except silver which is in pence per troy ounce of sterling silver, 0.925 fine. Copper quotations are for standard copper, spot and three months, and for electrolytic, price for the latter being subject to 3 per cent. discount. For convenience in comparison of London prices in pounds sterling per 2240 lb., with American prices in cents per pound the following approximate ratios are given, reckoning exchange at 4.80. £15 = 3.21c.; £20 = 4.29c.; £30 = 6.43c.; £40 = 8.57c.; £60 = 12.85c. Variations, £1 = 0.21½c.

Other Metals

NEW YORK—Feb. 9

Aluminum—The market is inclined to be quiet, but is steady, and little or no change is evident. Quotations are 54@56c. per lb. for No. 1 ingots, New York.

Antimony—The market is active and strong. Demand is fully up to supplies. Chinese and other ordinary brands are sold at 44@44½c. per lb. Cookson's is very scarce and is held at 57c. per lb. A little has been done in futures at 33½@34½c. in bond. Antimony ore has sold for $2.25 per unit.

Quicksilver—The market has been rather quiet for most of the week, but on Tuesday a considerable inquiry developed, and it closes very firm, with supplies below the demand. The New York price is $275@300 per flask for large lots, while $290@300 per flask is paid for smaller orders. San Francisco reports by telegraph $300@310 per flask with the market quiet and stocks small. London price appears to be fixed at £16 15s. per flask, with no discount from second hands.

Nickel—The market is steady with about the usual business doing. Quotations are 45@50c. per lb., New York, for ordinary forms, with 5c. per lb. more asked for electrolytic nickel.

Arrivals at Baltimore for the week included 245 tons of nickel matte from Noumea, New Caledonia.

Minor Metals—Current quotations for **Bismuth** are $4 per lb., New York.—**Cadmium** is quoted at 7s. per lb. in London; $1.50 per lb., New York.—**Chromium metal,** 75c. per lb., New York.—**Cobalt metal,** 97% pure, is sold at $1.25@1.50 per lb.—**Magnesium, pure,** has gone to a high price, $6 per lb. being asked.—**Selenium** varies from $2.50@3 per lb., New York, for large lots; $4.50@5 for retail quantities.

Gold, Silver and Platinum

Gold in the United States Feb. 1 estimated by the Treasury Department as follows: Held in Treasury against gold certificates outstanding, $1,517,533,186; in Treasury current balances, $185,491,144; in banks and circulation, $625,397,505; total, $2,328,421,835. This is an increase of $15,977,346 during January.

Platinum—The market is still irregular and sales are small. There is no improvement in supplies except that some small lots have been received from Colombia. Sales have been made at $85@95 per oz. for refined platinum, and in one case $98 is reported paid for a small lot.

Iridium is very scarce and high prices are named. It is difficult to quote, each transaction being a matter of negotiation and close figuring.

Coined Silver in the United States Feb. 1 is estimated by the Treasury Department as follows: Standard dollars, $568,271,655; subsidiary coins, $189,099,208; total, $757,370,863. Of the standard dollars $480,719,356 are held in the Treasury against silver certificates outstanding.

Silver—The undertone of silver continues steady. No new features control the market; supplies are not more than sufficient to meet the English and Continental demand. Some moderate amounts have been shipped to South American ports. London stock at latest advices was estimated at 5,500,000 oz.

Zinc and Lead Ore Markets

PLATTEVILLE, WIS.—Feb. 5

The base price paid this week for 60% zinc ore was 110@114 per ton. The base price paid for 80% lead ore was $78 per ton.

SHIPMENTS WEEK ENDED FEB. 5

	Zinc Ore, Lb.	Lead Ore, Lb.	Sulphur Ore, Lb.
Week	4,942,000	65,000	637,400
Year	20,252,000	365,700	3,871,000

Shipped during week to separating plants, 4,372,000 lb. zinc ore.

JOPLIN, MO.—Feb. 5

Blende, high price $119.50; base per ton 60% zinc, premium ore, $115@119; medium grades, $115@105, and lower grades down to $100; calamine, per ton 40% zinc, $70@80; average selling price, all grades zinc, $107.52 per ton. Lead, high price, $83.70; base, per ton 80% metal contents, $82@83.50; average selling price, all grades of lead, $81.57 per ton.

SHIPMENTS WEEK ENDED FEB. 5

	Blende	Calamine	Lead	Values
Totals this week	12,554,490	1,055,340	1,753,020	$803,220
Totals this year	61,324,860	6,099,900	9,488,570	3,884,690

Blende value, the week, $696,820; 5 weeks, $3,300,730.

Calamine value, the week, $34,900; 5 weeks, $217,670.

Lead value, the week, $71,500; 5 weeks, $366,290.

Again the reserve stock was invaded, and reports tonight are that it is all sold. There was rapid action in buying this afternoon and prices climbed from $110 to $115, $117.50 and $119, with undenied rumors that efforts are being made at a late hour tonight to buy practically all of next week's output at $120 or higher.

Constructing a dam in one mine in north Webb City gave temporary relief, then it broke, was rebuilt, and a pressure test this evening indicated it could stand very little additional strain. Additional pumps are to be installed tomorrow and every effort made to hold it back until large pumps ordered for delivery in March can be installed. Fuel shortage continues a detriment to outputting.

PRODUCTION IN 1915

Owing to the December shipments of zinc and lead ores being so far in excess of the estimated totals in the annual "Journal" the following table is given. It also includes year totals from Green and Dade counties in Missouri that could not be secured early enough for inclosure in the annual report:

JOPLIN DISTRICT ORE SHIPMENTS, IN POUNDS, 1915

Missouri	Blende	Calamine	Lead	Values
Jasper County	449,280,070	5,063,910	65,098,460	$20,436,660
Newton County	32,234,170	35,747,950	3,726,360	2,185,260
Green County	4,013,900	.....	43,730	267,230
Lawrence County	1,882,640	8,045,510	236,000	275,760
Dade County	.....	2,157,000	.....	64,710
Total Missouri	487,410,780	51,014,370	69,104,550	$23,227,620
Oklahoma				
Ottawa County	53,399,530	230,280	20,339,960	2,755,150
Kansas				
Cherokee County	56,899,670	113,000	3,780,870	2,414,260
Total 1915	597,699,980	51,357,650	93,225,380	$28,397,030
Total 1914	510,787,430	39,031,880	84,551,000	12,839,040

This shows for 1915, as compared with 1914, increases of 86,912,550 lb. in blende; 12,325,770 lb. in calamine; 8,674,380 lb. in lead ore; and $15,557,990 in values.

Iron Trade Review

PITTSBURGH—Feb. 8

The steel market has experienced a further slowing down in the past week as to the volume of strictly new business placed, and there is probably also a decrease in the rate of specifying against contracts, but the condition is attributed to the fact that mills are already not only sold up but in most cases uncomfortably oversold, while on the other hand buyers have largely covered for their requirements and are much more interested in securing deliveries on material already ordered than in filling the mills with further obligations.

On Feb. 4 the Carnegie Steel Co. advanced prices on bars, plates, shapes and hoops $2 a ton, to 2c. on bars and shapes, 2.10c. on plates and 2.20c. on hoops. These advances at once became the general market for delivery at mill convenience, while early shipments, possible with some of the smaller mills, readily command premiums, in some cases higher than those ruling 30 days ago. The large mills are sold up fully for six months or more.

Effective yesterday morning the Pennsylvania R.R. lifted its embargo on steel shipments to Eastern consumers, while the condition as to exports remains that shipment will be accepted if the vessel is ready to take the goods. The steel mills are hastening to ship steel to consumers who have been badly incommoded in the past few weeks, particularly as another congestion is feared.

Indications are that the large steel interests have become averse to further price advances of consequence, and will leave market prices as they stand until they can see farther ahead. Their problem now is to manufacture and ship a tonnage equal to more than six months of full operation, with orders still coming in freely on old contracts.

Pig Iron—The market continues stagnant, and buyers and sellers have dropped into one of their customary waits to see which side will make a move first. We quote: Bessemer, $21; basic, malleable and forge, $18@18.50; foundry, $18.50@19, f.o.b. Valley furnaces, 95c. delivered Pittsburgh.

Steel—The situation has loosened up a trifle, consumers being somewhat more able to pay high prices for billets and sheet bars, while producers seem to be in somewhat better position to consider early deliveries. We quote billets and sheet bars at $33 for bessemer and $35 for openhearth, the quotations being largely nominal, but not as much so as in recent weeks. Rods are about $45 at mill.

Ferromanganese—The market is still stronger, and an acute scarcity is among the possibilities. Buyers are evidently not very well covered. We quote contract at $125, subject to quite late delivery, and spot at about $175, with near-by deliveries ranging between.

Scotch Pig Iron in 1915 showed a total make of 1,108,588 tons, a decrease of 31,768 tons from 1914. Exports were 184,031 tons; consumption, 985,649 tons; and the decrease in stocks on hand during the year was 61,094 tons.

NEW YORK—Feb. 9

While there is some cessation in new orders, chiefly owing to uncertainty as to deliveries, there is no decrease in the general activity and demand for iron and steel.

Transportation difficulties are still a prominent feature, and the railroads are unable to handle the business pressing upon them, many delays being the result. Very cold weather and storms have made some delay in production at the mills, and have also helped to increase the railroad troubles and delays.

The pig-iron market is fairly active and is generally firm. The demand for foundry iron is increasing, but basic is not especially active just at present.

The negotiations for the Cambria-Youngstown-Lackawanna merger are all off, the bankers who were to underwrite the consolidation having withdrawn. It is understood that the underlying bonds of the companies constituted one difficulty. Immediately following this announcement another and unexpected one was made. A syndicate headed by W. E. Corey purchased the controlling interest in the Cambria Steel Co. for the recently formed Midvale Steel and Ordnance Co.

January production of pig iron in Alabama was 227,805 tons, being the largest monthly output ever reported. It was 83,042 tons more than in January of last year.

Pig Iron Production—The statements of the furnaces as collected and published by the "Iron Age" show that on Feb. 1 there were 307 coke and anthracite stacks in blast, having a total daily capacity of 107,200 tons; an increase of 1,800 tons over Jan. 1. Production in January was a little less than in December, chiefly owing to the Youngstown strike, which compelled the banking of several furnaces. Making allowance for the charcoal furnaces the total make of pig iron in January was 3,220,900 tons. Of this 2,283,047 tons, or 70.9%, was made by the steel works furnaces.

Exports and Imports of Iron and Steel in the United States 11 months ended Nov. 30, so far as those articles reported by quantities are concerned, were as follows, in long tons:

	1914	1915	Changes
Exports	1,431,748	3,159,346	I. 1,727,598
Imports	280,902	246,994	D. 33,908

The larger items of exports in 1915 were 510,816 tons billets, ingots and blooms; 425,301 tons wire; 389,722 tons bars; 350,660 tons rails; 294,657 tons plates and sheets; 214,017 tons structural steel; 202,692 tons pig iron; 137,589 tons tinplates. Exports of machinery were valued at $85,446,623 in 1914 and $122,858,811 in 1915, an increase of $37,412,188 last year.

FERROALLOYS

Ferromanganese has advanced sharply and is in active demand, some sales as high as $200 per ton being reported. **Ferrosilicon** of high grade is also strong, 80% alloy being quoted at $95@100 per ton, Pittsburgh Bessemer ferrosilicon of lower grade has also been advanced $2 or $3 per ton.

IRON ORE

Arrivals at Baltimore for the week included 5,800 tons of iron ore from Bizerta in Tunis.

Imports of iron ore into the United States 11 months ended Nov. 30 were 1,299,535 long tons in 1914, and 1,222,960 in 1915; decrease, 76,575 tons. The larger imports in 1915 were 750,198 tons from Cuba, 198,186 from Sweden, 82,795 from Canada and 38,946 from Spain.

A strike at the iron ore mines of the Empire Steel and Iron Co. at Mt. Hope and the Thomas Iron Co. at Wharton, N. J., was settled by an advance of 10% in wages.

OTHER ORES

Molybdenite, 85 to 90% MoS_2, is quoted at $1.40@1.45 per lb. The demand is rather light. A sale of 90% ore is reported at $1.42 per lb., New York.

The Board of General Appraisers on an appeal from the collector of customs at New York has decided that molybdenite is free from duty as a crude mineral. The collector had assessed 20% duty as a mineral substance partly manufactured.

Tungsten Ore is quoted at $65 per unit for February and March shipment.

COKE

Coke production in the Connellsville region for the week is reported by the "Courier" at 442,616 short tons; shipments, 442,598 tons. Shipments from Greensburg and Upper Connellsville districts were 42,278 tons.

The Gulf States Steel Co., Birmingham, Ala., has let a contract to the H. Koppers Co., Pittsburgh, for a battery of 37 byproduct coke ovens, to have a daily capacity of 450 tons.

The United States Steel Corporation has plans completed for the erection of 204 byproduct coke ovens, work on which will be begun in the spring.

NEW CALEDONIA ORES

Exports of ores from New Caledonia 11 months ended Nov. 30 are reported by the "Bulletin du Commerce" of Noumea at 45,476 metric tons of nickel ore and 55,450 tons of chrome ore. Exports of metals were 1,452 tons nickel matte.

EXPORTS AND IMPORTS

Imports of Zinc into the United States November and the 11 months ended Nov. 30 are reported by the Department of Commerce as below, in pounds:

	November	11 Months
Zinc contents of ore	4,822,319	86,178,269
Zinc, metallic	134,430	1,661,274
Total zinc	4,956,749	87,839,543
Zinc dust	77,130	1,414,257

The actual tonnage of ore imported in November was 3,162 tons from Mexico, 1,836 from Canada, 917 from Australia and 28 tons from Peru.

Exports of Zinc from the United States November and 11 months ended Nov. 30, as reported by the Department of Commerce in pounds; ore in tons:

	November	11 Months
Zinc pigs, bars, plates, etc.	24,724,189	231,595,956
Zinc dross	4,167	8,333,503
Zinc ore	.....	743

In addition manufactures of zinc—weight not given—were exported, valued at $74,426 in November and $2,059,996 in the 11 months. Of the metal exported in November 4,685,899 lb. were made from imported ore.

Imports of Lead into the United States November and the 11 months ended Nov. 30 are stated by the Department of Commerce as below, in pounds:

	November	11 Months
Lead contents of ore	1,785,600	17,032,454
Lead in bullion and base bullion	2,320,793	84,972,667
Lead, metallic	8,594	777,437
Total lead	4,114,987	102,782,558

In addition manufactures of lead—weight not given—were imported, valued at $34,505 in November and $84,084 in the 11 months. Actual tonnage of ore imported in November, 4,852, of which 2,349 tons came from Mexico.

Chemicals

NEW YORK—Feb. 9

The general market is steady and a fair amount of business is being done in heavy chemicals.

Arsenic—Demand is improving and the market is again firmer, dealers quoting $5@5.25 per 100 lb. for early deliveries.

Copper Sulphate—The market is steady, with supplies not very large and sales only moderate. Quotations are $22 per 100 lb. for carload lots and $22.25 per 100 lb. for smaller parcels.

Nitrate of Soda—Demand continues large and prices are firm, with only moderate stocks. Current price is $3.60 per 100 lb. for early deliveries, with future shipments slightly lower.

Pyrites—The market is firm and prices are rather high. Spanish pyrites are quoted at 16c. per unit of sulphur for lump and 14c. for fines. Some adjustments will have to be made for the ocean freight rates, which are now as high as 22s. 6d. per ton, against 10s. a year ago. American pyrites are rather scarce, owing to the cave at the Arminius mine, which has stopped production there. Virginia pyrites are quoted at 10@14c. per unit for fines, according to grade. Supplies are scarce and some domestic companies claim that they are entirely sold out for the present year.

Arrivals at Baltimore for the week included 16,853 tons of pyrites from Huelva, Spain.

Sulphate of Ammonia—The production of sulphate of ammonia in Great Britain in 1915 is estimated at 423,000 long tons, a decrease of 3,000 tons from 1914, and of 9,000 tons from 1913. The production in the United States in 1915 is estimated at 212,000 tons, an increase of 17,000 tons over the preceding year.

Sulphuric Acid—Current quotations for 60% acid are $25 per ton for prompt shipments and $22 for futures; price at works, buyers to supply tank cars.

PETROLEUM

New oil wells completed in January, according to the monthly statement of the "Oil City Derrick," were: Pennsylvania grade, 389; Lima-Indiana, 50; Central Ohio, 56; Kentucky, 71; Illinois, 93; Kansas, 156; Oklahoma-Arkansas, 642; Texas Panhandle, 32; North Louisiana, 44; Gulf Coast, 101. The total number was 1,634, with an aggregate daily production of 174,285 bbl. There were 147 gas wells and 279 dry holes. On Jan. 31 there were 2,926 wells under the drill.

Assessments

Company	Delinq.	Sale	Amt.
Albany Lead, Ida	Jan. 20	Feb. 19	$0.005
Alta-Germanic, Utah	Feb. 8	Feb. 28	0.005
Alta Tunnel, Utah	Feb. 15	Mar. 4	0.01
Atlantic, Ida	Jan. 21	Feb. 21	0.005
Basalt, Nev	Mar. 8	Apr. 6	0.003
Beaver Copper, Utah	Jan. 31	Feb. 21	0.005
Belmont, Ida	Feb. 15	Mar. 11	0.003
Boston Development	Feb. 17	Mar. 8	0.05
Cash Boy, Nev	Feb. 16	Mar. 20	0.01
Columbia Ex., Utah	Feb. 23	Mar. 14	0.025
Deer Creek C. & G., Utah	Feb. 5	Feb. 26	0.005
Emerald, Utah	Feb. 15	Mar. 11	0.00½
Emerald, Utah	Mar. 15	Apr. 11	0.00½
Exchequer G. & S., Nev.	Feb. 16	Mar. 8	0.03
Great Copper King, Utah	Feb. 14	Mar. 11	0.001
Imperial, Ida	Feb. 19	Mar. 20	0.003
Independence, Utah	Jan. 20	Feb. 14	0.001
Index, Ida	Feb. 6	Mar. 6	0.0025
Jacket-Crown Pt.-Belc., Nev.	Feb. 18	Mar. 10	0.06
Jack Waite, Ida., (post.)		Feb. 23	0 01
Laclede, Ida	Feb. 4	Feb. 28	0.003
Lucky Deposit, Utah	Feb. 11	Mar. 13	0.005
Massasoit, Utah	Jan. 13	Feb. 23	0.015
M. & P. Gold, Utah	Feb. 7	Feb. 21	0.0025
McKinley Gold, Ida	Jan. 28	Feb. 24	0.0005
Mexican Nev	Jan. 25	Feb. 16	0.10
Monarch Pitts., Nev	Feb. 18	Mar. 20	0.01
Nabob, Ida	Jan. 17	Feb. 14	0.005
Nevada-Douglas, Nev	Feb. 10	Mar. 10	0.10
Park Gold, Utah	Apr. 1	Apr. 20	0.001
Queen Bess, Utah	Feb. 20	Mar. 20	0.005
Revenue Cons., Utah	Feb. 5	Mar. 3	0.01
Rexall, Utah	Feb. 2	Feb. 21	0.01
Rio Grande Grubstake, Utah	Dec. 25	Feb. 29	0.006
Rob Roy, Ida	Feb. 5	Mar. 5	0.002
Santaquin King, Utah	Feb. 8	Mar. 8	0.00125
Scorpion, Nev	Feb. 21	Mar. 14	0.01
Silver Moon, Ida	Feb. 26	Mar. 22	0.005
Silver Mountain, Ida	Feb. 17	Mar. 17	0.002
Slavonian, Ida	Feb. 1	Feb. 29	0.001
Snowshoe, Ida	Feb. 15	Mar. 15	0.005
Summit Ex., Utah	Mar. 15	May 1	0.01
Tar Baby, Utah	Dec. 31	Feb. 28	0.005
Tyler M. & M., Ida	Jan. 28	Feb. 28	0.001
Utah-Oregon, Utah	Jan. 5	Feb. 10	0.0005
Uvada, Nev	Feb. 21	Mar. 20	0.02
Western Star, Ida	Jan. 10	Jan. 31	0.001

Stock Quotations

COLO. SPRINGS Feb. 8		SALT LAKE Feb. 7	
Name of Comp.	Bid.	Name of Comp.	Bid.
Acacia	.05¼	Beck Tunnel	.13
Cripple Cr'k Con.	‡.039	Black Jack	.12
Dante	.04	Colorado Mining	.14
Doctor Jack Pot	.10¼	Crown Point	.04
Elkton Con	.36	Daly-Judge	8.20
El Paso	.93	Emma Cop	.60
Findlay	.04	Gold Chain	.57
Gold Dollar	.03	Grand Central	.57
Gold Sovereign	.05	Iron Blossom	1.32½
Golden Cycle	2.14	Lower Mammoth	.06½
Isabella	.23¼	May Day	.19
Jack Pot	.05½	Opohongo	.02
Jerry Johnson	.06½	Prince Con	.84
Lexington	.004	Seven Troughs	.01½
Mary McKinney	.44	Silver King Coal'n	3.40
Pharmacist	.01¼	Silver King Con	2.35
Portland	1.76	Sioux Con	.09½
Raven B. H	.02½	Uncle Sam	.08½
Vindicator	2.43	Yankee	.28

SAN FRANCISCO Feb. 8			
Alta	.05	Belmont	4.25
Andes	.07	Jim Butler	.95
Best & Belcher	.03	Lone Star	.03
Caledonia	.45	MacNamara	.03
Challenge Con	.05	Midway	.16
Chollar	‡.02	Mont.-Tonopah	.25
Confidence	.20	North Star	.14
Con. Virginia	.08	Rescue Eula	.07
Gould & Curry	.01	West End Con	.72
Hale & Norcross	.03	Atlanta	.19
Jacket-Cr. Pt	.05	Blue Bell	.02
Julia	‡.01	Booth	.41
Mexican	.23	C.O.D. Con	.03
Occidental	.75	Comb. Frac	.07
Ophir	.20	D'field Daisy	.03
Overman	.05	Jumbo Extension	1.20
Savage	‡.04	Pitts.-Silver Peak	.08
Seg Belcher	.03	Round Mountain	.52
Sierra Nevada	.25	Sandstorm Kendall	.05
Union Con	.50	Silver Pick	.03
Utah Con	‡.01	Central Eureka	.10

TORONTO Feb. 1			
Bailey	‡.04¼	Dome Exten	.29
Chambers Ferland	.25	Dome Lake	.25
Coniagas	4.20	Foley O'Brien	.60
La Rose	.66	Hollinger	29.00
Peterson Lake	.25¼	Imperial	‡.04
Right of Way	‡ 06	Jupiter	.22½
Seneca Superior	.63	McIntyre	.97½
T. & Hudson Bay	25.00	Porcu. Crown	.81
Temiskaming	.66	Preston E. D.	‡.05
Trethewey	.16	Vipond	.75
Wettlaufer-Lor	.08	West Dome	.13½

LONDON Jan. 23			
Alaska Treadwell	£7 5s 0d	Mexico Mines	£4 0s 0d
Burma Corp	1 12 6	Nechi, pfd	0 14 0
Cam & Motor	0 13 0	Oroville	0 14 6
Camp Bird	0 7 0	Santa Gert'dis	0 10 0
El Oro	0 8 9	Tomboy	1 3 1½
Esperanza	0 10 0	Tough Oakes	0 11 10½

N. Y. EXCH. Feb. 8		BOSTON EXCH Feb. 8	
Name of Comp.	Clg.	Name of Comp.	Clg.
Alaska Gold M	24	Adventure	1¼
Alaska Juneau	9½	Ahmeek	399
Am.Sm.&Ref.,com	100¼	Algomah	.90
Am. Sm. & Ref., pf.	114	Allouez	71
Am. Sm. Sec., pf. A	92¼	Ariz. Com., ctfs	8¾
Am. Sm. Sec., pf. B	86¼	Bonanza	.35
Am. Zinc	69	Butte Alex. Scott	9¼
Anaconda	86¾	Butte-Balaklava	5
Batopilas Min	2¼	Calumet & Ariz	71
Bethlehem Steel	465	Calumet & Hecla	561
Bethlehem Steel, pf.	‡128	Centennial	17
Butte & Superior	79	Copper Range	64½
Chile Cop	22¼	Daly West	2¼
Chino	54¼	East Butte	15¾
Colo. Fuel & Iron	48½	Franklin	9¼
Crucible Steel	83¼	Granby	93
Dome Mines	29	Hancock	16
Federal M. & S.	31¼	Hedley	26
Federal M. & S., pf.	54½	Helvetia	.40
Great Nor., ore., ctf.	47	Indiana	5
Greene Cananea	47½	Island Cr'k, com	46
Guggen. Exp	23	Island Cr'k, pfd	88¾
Homestake	128	Isle Royale	28½
Inspiration Con	45½	Keweenaw	2¾
International Nickel	209	Lake	18
Lackawanna Steel	77	La Salle	4¾
Miami Copper	36¾	Mason Valley	3½
Nat'l Lead, com	70¾	Mass	12¼
National Lead, pf	113	Mayflower	3¾
Nev. Consol	15½	Michigan	1¾
Ontario Min	7¾	Mohawk	92
Quicksilver	5	New Arcadian	9
Quicksilver, pf	‡7¾	New Idria	20½
Ray Con	24¼	North Butte	28½
Republic I&S, com	53¾	North Lake	1¾
Republic I&S, pf	109	Ojibway	1¾
Sloss-Sheffield	60	Old Colony	3
Sloss-Sheffield, pf	97	Old Dominion	68½
Tennessee Copper	57½	Osceola	90½
Utah Copper	79½	Quincy	91½
U. S. Steel, com	84½	St. Mary's M. L	64½
U. S. Steel, pf	116½	Santa Fe	3
Va. Iron C. & C	56	Shannon	9¾

N. Y. CURB Feb. 8			
Alta Con	‡.20	Shattuck-Ariz	33½
Beaver Con	.39½	So. Lake	6¾
Big Four	.04	So. Utah	.34
Buffalo Mines	1	Superior	22
Butte & N. Y	2¾	Superior & Bost	3¼
Butte C. & Z	7¾	Tamarack	51½
Can. Cop. Corpn	1¾	Trinity	9¼
Cashboy	.05	Tuolumne	.18
Cerro de Pasco	40½	U. S. Smelting	60
Con. Ariz. Sm	1¾	U. S. Smelt'g, pf	50½
Con. Coppermines	1¾	Utah Apex	3¾
Con. Nev.-Utah	⅛	Utah Con	13½
Dia. Black B	.03	Victoria	3¾
First Nat. Cop	6¾	Winona	4
Florence	.47	Wolverine	64
Goldfield Con	.84	Wyandot	2¼
Goldfield Merger	.19		
Hecla Min	3¾		
Howe Sound	6¾		
Kennecott Cop	52		
Kerr Lake	4.40		
Magma	15⅜		
Majestic	1¾		
McKinley-Dar-Sa	.48		
Mines of Am	3		
Mother Lode	.21½		
Nevada Hills	.20		
New Utah Bingham	3¾		
Nipissing Mines	7.20		
Oro	.05		
Ray Hercules	3		
Rochester Mines	.59		
St. Joseph Lead	15¼		
Stand'd Oil of N.J.	515		
Standard S. L	1¾		
Stewart	1 1/16		
Success	.75		
Tonopah	6¾		
Tonopah Ex	4 7/16		
Tonopah Merger	.62		
Tribullion	1/16		
White Knob, pf	1.81½		
Yukon Gold	2¾		

BOSTON CURB Feb. 8	
Bingham Mines	7½
Boston Ely	.45
Butte & Lon'n Dev.	.37
Calaveras	3¾
Calumet-Corbin	.06
Chief Con	1½
Cortez	.70
Crown Reserve	.35
Davis-Daly	1½
Eagle & Blue Bell	1 3/16
Houghton Copper	2½
Iron Cap Cop., pf	7
Mexican Metals	.42
Nat. Zinc & Lead	2½
Nevada-Douglas	.80
New Baltic	3½
New Cornelia	12¼
Ohio Copper	.20
Oneco	.50
Raven Copper	.18
Rex Cons	.32
Rilla	1½
Smokey Dev	‡.30
United Verde Ext.	9
Utah Metal	8½

‡Last Quotations.

Monthly Average Prices of Metals

SILVER

Month	New York			London		
	1914	1915	1916	1914	1915	1916
January	56.572	48.855	56.775	26.553	22.731	26.953
February	57.506	48.477	.....	26.573	22.753	.....
March	58.067	50.241	.....	26.788	23.708	.....
April	58.519	50.250	.....	26.958	23.709	.....
May	58.175	49.915	.....	26.704	23.570	.....
June	56.471	49.034	.....	25.948	23.267	.....
July	54.678	47.519	.....	25.219	22.597	.....
August	54.344	47.163	.....	25.979	22.780	.....
September	53.290	48.680	.....	24.260	23.591	.....
October	50.654	49.385	.....	23.199	23.925	.....
November	49.082	51.714	.....	22.703	25.094	.....
December	49.375	54.971	.....	22.900	26.373	.....
Year	54.811	49.604	.....	27.314	23.675	.....

New York quotations cents per ounce troy, fine silver; London, pence per ounce, sterling silver, 0.925 fine.

COPPER

Month	New York		London			
	Electrolytic		Standard		Electrolytic	
	1915	1916	1915	1916	1915	1916
January	13.641	24.008	60.756	88.083	65.719	116.17
February	14.394	.....	63.494	.....	*	.....
March	14.787	.....	66.152	.....	*	.....
April	16.811	.....	75.096	.....	*	.....
May	18.506	.....	77.600	.....	*	.....
June	19.477	.....	82.574	.....	95.333	.....
July	18.796	.....	76.011	.....	91.409	.....
August	16.941	.....	68.673	.....	82.333	.....
September	17.592	.....	68.915	.....	85.250	.....
October	17.686	.....	72.601	.....	88.000	.....
November	18.627	.....	77.744	.....	93.273	.....
December	20.133	.....	80.773	.....	100.43	.....
Year	17.275	.....	72.532	.....	.....	.....

TIN

Month	New York		London	
	1915	1916	1915	1916
January	34.260	41.825	156.550	175.548
February	37.415	.....	176.925	.....
March	48.426	.....	180.141	.....
April	47.884	.....	166.225	.....
May	38.790	.....	162.675	.....
June	40.288	.....	167.636	.....
July	37.423	.....	167.080	.....
August	34.389	.....	151.440	.....
September	33.125	.....	152.625	.....
October	33.080	.....	151.554	.....
November	39.224	.....	167.670	.....
December	38.779	.....	167 000	.....
Av. year	38.500	.....	163.960	.....

LEAD

Month	New York		St. Louis		London	
	1915	1916	1915	1916	1915	1916
January	3.729	5.921	3.548	5.826	18.606	31.167
February	3.827	.....	3.718	.....	19.122	.....
March	4.053	.....	3.997	.....	21.883	.....
April	4.221	.....	4.142	.....	21.094	.....
May	4.274	.....	4.182	.....	20.347	.....
June	5.932	.....	5.836	.....	25.170	.....
July	5.659	.....	5.531	.....	24.611	.....
August	4.656	.....	4.520	.....	21.946	.....
September	4.610	.....	4.490	.....	23.151	.....
October	4.600	.....	4.499	.....	23.994	.....
November	5.155	.....	5.078	.....	26.278	.....
December	5.355	.....	5.266	.....	28.807	.....
Year	4.628	.....	4.587	.....	22.917	.....

SPELTER

Month	New York		St. Louis		London	
	1915	1916	1915	1916	1915	1916
Jan	6.386	16.915	6.211	16.745	30.844	89.810
Feb	8.436	.....	8.255	.....	39.819	.....
Mar	8.541	.....	8.360	.....	44.141	.....
April	10.012	.....	9.837	.....	49.888	.....
May	14.781	.....	14.610	.....	68.100	.....
June	21.208	.....	21.038	.....	100.614	.....
July	19.026	.....	18.856	.....	97.250	.....
Aug	12.781	.....	12.611	.....	67.786	.....
Sept	13.440	.....	13.270	.....	67.841	.....
Oct	12.800	.....	12.596	.....	66.536	.....
Nov	15.962	.....	15.792	.....	88.409	.....
Dec	15.391	.....	15.221	.....	89.400	.....
Year	13.230	.....	13.054	.....	67.553	.....

New York and St. Louis quotations, cents per pound, London, pounds sterling per long ton. * Not reported. ‡ London Exchange closed.

PIG IRON IN PITTSBURGH

Month	Bessemer		Basic		No. 2 Foundry	
	1915	1916	1915	1916	1915	1916
January	$14.59	$21.60	$13.45	$18.78	$13.90	$19.70
February	14.55	.....	13.45	.....	13.90	.....
March	14.55	.....	13.45	.....	13.95	.....
April	14.55	.....	13.45	.....	13.95	.....
May	14.64	.....	13.60	.....	13.83	.....
June	14.70	.....	13.67	.....	13.77	.....
July	14.94	.....	13.91	.....	13.68	.....
August	16.01	.....	15.31	.....	14.75	.....
September	16.86	.....	15.95	.....	15.70	.....
October	16.95	.....	15.96	.....	15.80	.....
November	18.26	.....	17.30	.....	17.20	.....
December	19.95	.....	18.95	.....	18.95	.....
Year	$14.89	.....	$13.76	.....	$13.89	.....